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Water Quality Research Status Report—1993

Beltsville Agricultural Research Center, Natural Resources Institute

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While supplies last, single copies of this report may be obtained at no cost from Jerry C. Ritchie, BARC-West, Hydrology Laboratory, Building 007, Room 110–A, Beltsville, MD 20705–2350.

Copies of this publication may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Contents

Preface

This is the fourth annual progress report on water quality research being conducted in the Natural Resources Institute, Beltsville Agricultural Research Center, United States Department of Agriculture. The report reflexs a large multi-faceted program that is aimed at: 1) developing a better understanding of the processes that influence the movement of agricultural chemicals into both surface and groundwater; and 2) developing methods for reducing that movement.

A common thread that runs through the whole report is the use of the herbicide atrazine and nitrate, as two chemicals routinely detected in water samples.

Process research has been directed primarily at tillage systems used widely in U.S. agriculture. No-till appears to cause lower pesticide residues in soils when compared to conventional tillage, probably due to the higher organic matter and associated microbial activity in no-till systems. Research in our chemical transport groups has expanded considerably since the previous report. Large scale field experiments coupled with controlled laboratory studies are giving us some better insights on the importance of rainfall timing, frequency and duration on pesticide movement. Our understanding of preferential flow in soil is also improving with the observation that it occurs in both tillage systems. An extensive atmospheric transport and water study on pesticides was undertaken on the Chesapeake Bay. The residues detected in both air and water reflect regional pesticide use.

Methods to reduce residues are occurring on several fronts. Starch encapsulation is reducing both leaching and volatility from field application of several herbicides. Extensive evaluation of a soil nitrogen test for corn in Maryland has identified nitrogen sufficient sites that will reduce the fertilizer inputs and thus nitrate movement to groundwater. Bioremediation of pesticide contaminated soils has been actively pursued in two areas: the isolation and characterization of microbial enzymes and genes responsible for atrazine metabolism; and the use of selected soil microorganisms to decontaminate specific sites. Although some progress has been made in engineering organisms for directed metabolism, it is unclear at this time just what role gene engineering will play in remediation of contaminated soils. The use of indigenous microbes to destroy an organophosphate insecticide in soils shows considerable progress.

Philip C. Kearney
Institute Director
Natural Resources Institute

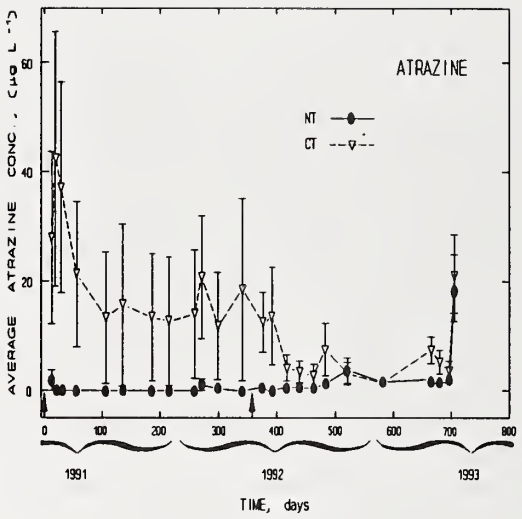
Executive Summary

Over the past 4 years several laboratories in the Natural Resource Institute (NRI) of the Beltsville Agricultural Research Center (BARC) have been involved in research on issues related to water quality. Results for calendar year 1993 are given in this report. Some of the significant results from this research since 1990 are:

- A soil N test for corn was evaluated and successfully deployed in Maryland which measures the NO_3-N concentration in the surface foot of soil when corn is 6-12 inches tall and thus allows the farmer to adjust future fertilizer N application accordingly. The test can successfully identified N sufficient sites and is being tested in Maryland to prevent over-fertilization and reduce NO_3-N losses to groundwater and the Chesapeake Bay.

- Field-scale atrazine concentrations below the root zone were consistently lower when applied as starch-encapsulated material than the typical commercial formulations.

- Although no difference in bromide concentration were observed below the root zone of four 0.3 ha fields (over 2 year period), atrazine



concentrations were lower under no-tillage perhaps indicating enhanced biological degradation under no-tillage.

- Isolated and characterized a novel bacterial enzyme that may prove useful for degrading s-triazine compounds in agricultural wastes.

- Tested protype unit (ca. 50 gal capacity) to dispose of pesticide contaminated water; complete mineralization to carbon dioxide and salts of the more recalcitrant pesticide (atrazine) was achieved.

- Demonstrated that indigenous microorganisms can be used to rapidly remediate soils that are contaminated with high concentrations of the

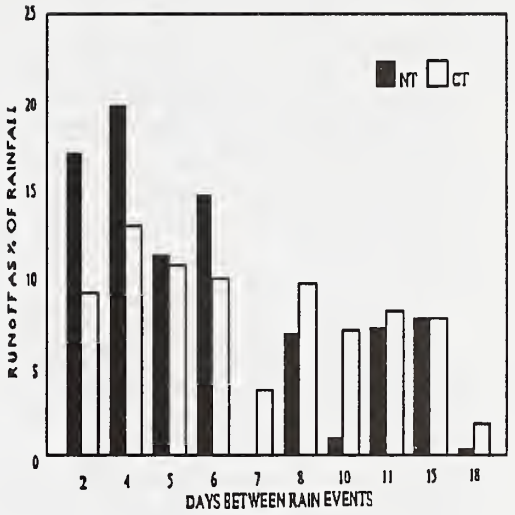
organophosphate insecticide coumaphos.

- Developed a Pesticide Properties Database (PPD) of chemical and physical properties of commonly used pesticides for use by Soil Conservation Service, modelers, and others to predict the potential of various pesticides to move to the groundwater. The database is online and can be used interactively by the user.

- Grass winter cover crops are better recyclers of corn fertilizer N than legumes. Rye recovered 50-60% of the residual fertilizer while hairy vetch or crimson clover recovered less than 10%. Grass cover crops should thus reduce nitrate loss into groundwater and the Chesapeake Bay. The Maryland Department of Agriculture has recently included grass cover crops for N assimilation as a cost share practice in their Maryland Agriculture Cost-share (MACS) program.

- Demonstrated that a granular starch-encapsulated herbicide dramatically reduced herbicide leaching (relative to technical grade) from no-till field cores subjected to preferential flow conditions.

- Found large seasonal changes in water infiltration rates and associated potential for rapid deep-percolation losses by preferential flow during seasons of high infiltration rates.



- Geostatistical analysis of 3 years field data showed that even a subtle difference in rainfall distribution (temporal) can result in marked spatial variability (regardless of the tillage practice) in the distribution of atrazine.

- Two years runoff data showed greater amounts of water runoff from no-till than for conservation till when the time between rainfall events was >7 days, but less when <7 day passed between rain events.

- Evaluated volatility of commercial and starch-encapsulated atrazine and alachlor in bare soil

ecosystem chambers under three soil temperatures. Demonstrated that volatilization losses of starch-encapsulated atrazine was an order-of-magnitude less than for the commercial formulation.

- Phenolic compounds in environmental samples may cause false levels of genotoxic/mutagenic activity as determined by bacterial assays.

- Extracts of ground water from agricultural areas demonstrate low levels of geontoxicity (approximately 2x's background) as determined by a bacterial test (SOS microplate assay/*Escherichia coli* PQ37).

- Demonstrated that preferential herbicide transport on a field-scale can take place under both no-till and conventional tillage.

- Demonstrated that soil residue values by themselves are a poor indicator of field-scale herbicide behavior.

- Studies with nitrogen (N) limited spinach plants, and N limited, non-N_2-fixing soybean plants, suggest that metabolic adjustments which enable these plants to tolerate N stress are 1) maintenance of foliar photosynthetic capacity at a level sufficient to support reasonable productivity and 2) reduction of their shoot mass while their root growth and mass is maintained or enlarged to facilitate their ability to continue to compete for available soil nitrogen and water.

- Determined the release characteristics of starch encapsulated atrazine and alachlor as a function of water potential, temperature and biological activity. Determined that herbicide release characteristics are governed by a diffusion process.

- Extracts of soil leachates show higher levels of genotoxicity (10-20x's) than do extracts of groundwater from agricultural areas.

- Developed a pretreatment extraction methodology for starch-encapsulated materials, that for the first time, allows quantitative analysis of starch-encapsulated herbicides. Methodology increased qualitative recovery by 50% and adds only 30 minutes to the typical analytical procedures.

- There is a positive correlation between total organic carbon levels and genotoxicity.

- Demonstrated that preferential transport of

surface broadcast herbicides could be a significant contributor to shallow ground water pollution (~1 m). Used geostatistical analysis to define tillage practices that were contributing to ground water contamination.

- Determined soil physical properties and characteristics which are critical in obtaining estimates of soil water retention.

- Field-scale mobility and persistence of commercial and starch-encapsulated atrazine and alachlor were determined. Starch-encapsulated atrazine, it's release being governed by a diffusion process, exhibited a dramatic reduction in mobility, and an increased persistence. The reduction in atrazine mobility was attributed to atrazine movement into the smaller pores of the soil matrix, where it is less susceptible to preferential transport.

- Captan, a fungicide, preferentially creates more adenine-thymine mutations, whereas, most mutagenic pesticides cause guanine-cytosine mutations.

- Field-scale volatilization losses of commercial and starch-encapsulated atrazine were evaluated under both conventional and no-till practices. Herbicide volatilization losses were initially higher (<6 d) under no-till. However, rain events washed the commercial formulation below the surface litter which created a stagnant vapor boundary, reducing volatilization losses. Starch-encapsulated volatilization losses were much less than the commercial formulations.

- Compared volume-averaged leachate levels of atrazine, alachlor, bromide and nitrate below the active root zones of conventional and no-till fields (using suction lysimeters at 1.5 & 1.8 m). Bromide data indicates that preferential transport was sampled for both tillage practices. Herbicide and nitrate levels were much lower under no-till than conventional tillage. Reduced herbicide levels under no-till attributed to enhanced biological activity in the preferential flow pathways, while annual soil disturbance in conventional tillage minimizes/eliminates the accumulation of organic material in preferential flow pathways.

- The concentration of pesticides in the surface soil is lower under no-till than under conventional till production practices.

- A root zone model (PRZM) simulation with field data for atrazine showed good agreement for the top 10 cm soil depth in conservation till plots but underestimated concentration for the no-till plots. (PRZM does not account for preferential flow).

- Laboratory studies have shown that 1) pesticide leaching potential is higher at high compared to low rainfall intensities, 2) increasing the amount of crop residue decreases leaching, and 3) living vegetation is more effective in reducing leaching than dead vegetation.

- Found a direct correlation between fish liver lesions measured with classical histological methods and those measured with magnetic resonance imaging and spectroscopy.

- Developed NUMEX, a combined expert system and laboratory information system for soil testing laboratories that can be used to make recommendation to the farmers about nutrients application thus leading to a significant reduction in nutrient leaching.

Introduction

This report covers the activities of scientists in the Natural Resources Institute (NRI), Beltsville Agricultural Research Center (BARC), who are involved in research related to water quality. The report has been divided into four (4) section.

Section 1 covers the research accomplished in CY 1993. A short narrative of the purpose, accomplishment, and application of the different research is given. These narratives have been adapted from the 1993 CRIS Annual Reports.

Section 2 contains a list of papers published or accepted for publication in 1990-1994.

Section 3 contains a list of papers with interpretive summaries and technical abstracts that have been reviewed and approved for publication by ARS in 1992 and 1993. These summaries are available in the ARS TEKTRAN (Technology Transfer Automated Retrieval System).

Section 4 contains a list of scientists with addresses and phone numbers.

Summary

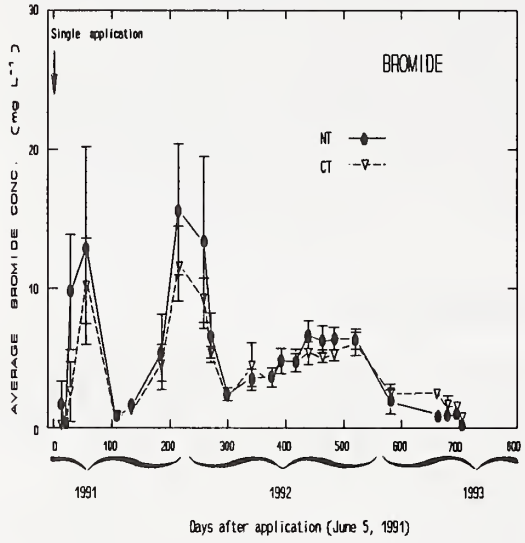
BARC scientists are actively involved in research to help better understand and manage water quality. Research is underway to 1) develop data bases, 2) develop expert systems, 3) develop and validate models, 4) measure and understand N and pesticide transport, 5) measure and understand volatilization and its impact on chemical loss, 6) develop methods to biodegrade pesticide wastes, 7) develop management systems to minimize N and pesticides loss from agricultural fields, 7) studies of biological effects, and 9) develop basic and theoretical understanding of chemical transport in agricultural, riparian, and natural ecosystems.

Disclaimer

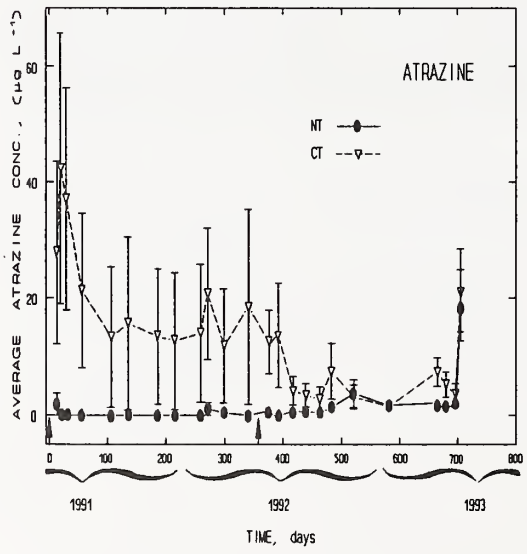
Hopefully this compilation is representative of the research on water quality at BARC. I have probably missed some research that should have been included. If I have, let me know so that we can all know the complete water quality program at BARC. If you have any general questions call me (Jerry C. Ritchie 301-504-7490). If you have technical questions call the scientist doing the research and see how you can become involved.

Section 1—Research Accomplishments 1993

Herbicide Transport Below the Root Zone of a Well-Drained Soil



In four well drained fields (0.3 ha each), bromide (a single pulse) and atrazine (annual applications) were monitored below the root zone (≈ 1.7 m). Two fields were under no-tillage (NT) management while two were under conventional tillage (CT). There were three distinct bromide peaks during the two years: a preferential flow peak, a bulk transport peak and a long diffuse tailing peak. No significant difference in bromide concentrations were observed with tillage. However, atrazine concentrations were lower under no-tillage than conventional tillage. A possible explanation may be that microorganism are preferentially located in the preferential flow channels associated with no-tillage practices and can thus degrade organics that move preferentially.



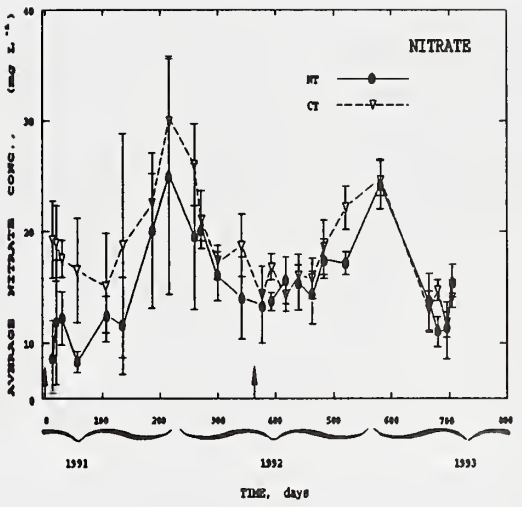
CRIS 0500-00032-004-00D
DRS. GISH/WIENHOLD

Variability and Runoff Loss of Pesticide Under No-Till and Conventional-Till Practice in Field

Because of the rapid change in agricultural management systems from conventional tillage practices to conservation tillage methods and thereby possible use of more pesticides, especially in the no-till systems, the public concern regarding the impact of agriculture on water quality has increased dramatically. This field research was initiated to achieve fundamental understanding of the pesticide

transport processes as influenced by tillage and environmental conditions. Results from two-year study on runoff and pesticide loss confirmed that: i) the amount of runoff from different tillage practices was primarily dependent on the soil moisture at the time of the runoff event and rainfall patterns; and ii) the total pesticides loss (regardless of the tillage systems) was less than 2% of the initial application. The total loss never exceeded 2% of the amount applied, even when rain occurred soon after application (worst case scenario). Furthermore, analyses of the soil and well water samples, using kriging techniques as a means of interpolating, demonstrated that even a subtle difference in rainfall distribution (temporal) can result in marked spatial variability in the distribution of herbicide.

CRIS 1270-13000-003-00D
DRS. SADEGHI/ISENSEE



concentrations between tillage practices were rare, but when they occurred no-tillage nitrate levels were always the lowest. Two year nitrate averages were also lower under no-tillage (12 mg L^{-1}) than conventional tillage (18 mg L^{-1}). Decreased nitrate levels under no-tillage may be due to N immobilization and denitrification.

CRIS 1270-13610-002-00D
DR. GISH

Nitrate Levels Below the Root Zone of a Well Drained Soil

Nitrate levels below the root zone were monitored on four 0.3 ha fields. Two fields were under conventional tillage (CT) and two under no-tillage (NT). Over a two year period nitrate concentration were significantly greater than 10 $\mu g\ L^{-1}$ for all tillage treatments. Due to spatial variability, significant differences in nitrate

Improving Nitrogen (N) Fertilizer Use Efficienty

Improving nitrogen (N) fertilizer use efficiency is an important task because it will ensure that farmers are able to supply ample N to meet crop demands, yet avoid excessive N applications that could cause nitrate pollution of groundwater or the Chesapeake Bay. The pre-sidedress nitrate test (PSNT) is one tool to improve N fertilizer use efficiency.

Agricultural researchers in Pennsylvania, Maryland, and Delaware evaluated 221 field trials which utilized the PSNT for corn. The PSNT test measures the nitrate concentration in the top foot of soil when the corn is about 12 inches tall, which is about two weeks before normal sidedress fertilizer N is applied. In 82 % of the cases the test successfully identified N sufficient sites, that is, identified sites which need no additional fertilizer. The accuracy of the test was not affected by tillage practices. The PSNT was most useful for manured fields where uncertainties in application rates and ammonia N losses make N management very difficult. This test will help extension agents, nutrient management consultants, and farmers identify N sufficient sites and thereby conserve fertilizer N and reduce nitrate losses to groundwater and the Chesapeake Bay.

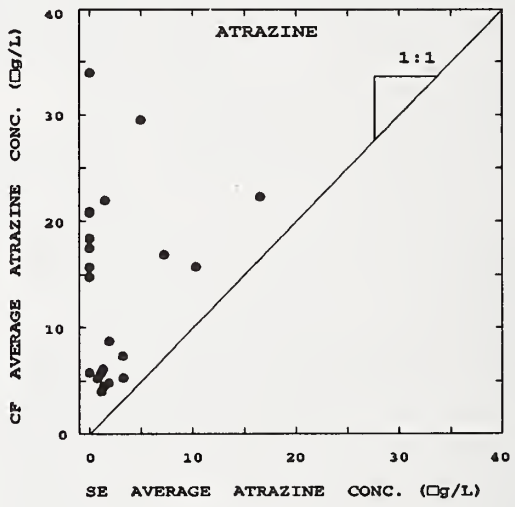
CRIS 1270-12310-004-00D
DR. MEISINGER

Impact of Tillage Reversal on Pesticide Leaching

Tillage was reversed in well established no-till (NT) and conventional-till (CT) plots to verify the relationship between tillage and pesticide transport patterns. In 1993 tillage was reversed in corn fields that had been in NT and CT for 7 years. Atrazine, alachlor and cyanazine were uniformly applied to all fields and the leaching of these herbicides into shallow groundwater was determined with time. Amounts of all three herbicides leached to confined groundwater were 2 times higher under the new NT than new CT, confirming the impact of tillage on leaching. Results were unexpected since development of macropores under NT conditions has been assumed to require several years establishment to affect pesticide leaching. These results suggest that tillage may influence preferential flow and pesticide transport more rapidly than previously thought.

CRIS 1270-13000-003-00D
DRS. ISENSEE/SADEGHI

Atrazine Formulation Effects on Leaching



Atrazine leachate concentrations below the root zone (≈ 1.7 m) of four fields was monitored with solution

samplers over a two year period. Atrazine solution phase concentrations were always greater with the commercial formulation. The greatest concentration differential was shortly after application when the commercial formulation was greatest and non-detectable for the starch encapsulated treatments. Reduced leachate levels, and lower cumulative volatilization (last years report) indicate that starch encapsulation may be a viable alternative to reducing detrimental impact of herbicides on the environment.
CRIS 1270-13610-002-00D
DRS. GISH/WIENHOLD

Measurement and Modeling of Pesticide in Field

The predictive capability of the Pesticide RootZone Model (PRZM) was evaluated with field data obtained during three growing seasons (1986-88) for atrazine in corn under no-till and conventional till management practices. Results from the comparison of model simulations with field observations showed a good agreement for the top 10 cm soil depths in the conventional tillage Plots, but underestimated for the no-till Plots. Overall, the model estimation of atrazine residues for the lower soil depths in both tillage practices were significantly lower than the measured values, especially in the no-till plots. The reason that PRZM underestimated the amount of atrazine at the lower soil depths is because PRZM does not account for the macropore flow. Testing and validation of other models (GLEAMS and RZWQM) with our field data are under consideration. The findings of this on-going long-term field research have also been shared with both regulatory and research organizations such as USEPA, USGS, and universities.

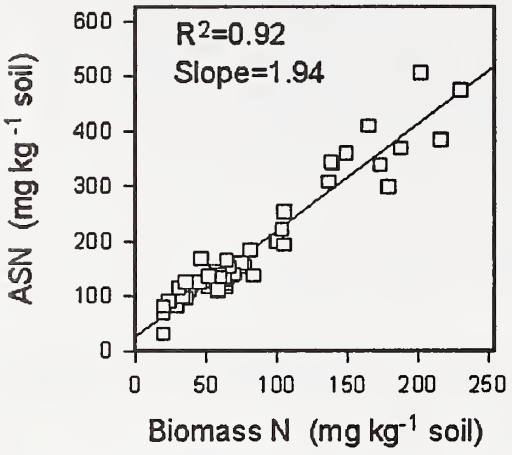
CRIS 1270-13000-003-00D
DRS. SADEGHI/ISENSEE

Influence of Rainfall Timing and Soil Moisture on Pesticide Leaching

Field studies have shown that both rainfall timing and soil antecedent moisture level at the time of pesticide application may affect pesticide leaching, but the magnitude of the leaching is highly variable. The leaching of atrazine through both NT and CT soil cores was reduced by 50% when time between application and the rain was increased from 1 to 14 days. Reducing the soil moisture content at the time of pesticide application from near saturation to wilting point significantly reduced leaching through NT cores, but had no effect on leaching through CT cores. These results help explain field experiments where two similar rains may result in very different amounts of pesticide leaching under NT conditions.

CRIS 0500-00032-004-00D
DRS. ISENSEE/SIGUA/SADEGHI

Assessing the Active Soil Nitrogen Pool Size in Soils Under Plow- and No- Tillage Treatments



Relationship between active soil N (ASN) and biomass N in soil.

To develop improved N management practices for reduction of nitrate contamination of ground water, it is essential to gain a better understanding of the interaction of fertilizer N with the various pools of soil N. Studies to characterize the active N pool in soils under long-term plow- and no-tillage treatments have indicated that there is a substantially greater potential for interaction of fertilizer N with active N in no-till soils than in corresponding plow-till soils. Studies to characterize the relationship between active soil N and biomass N have demonstrated that there is a very high correlation between these N pools. Characterization of the relationship between active soil N and the processes involved in the mineralization-immobilization turnover of fertilizer N in soil should improve our understanding of the fate of fertilizer N in agricultural ecosystems and the potential for movement of this N into ground water.

CRIS 0500-00038-006-00D
DR. McCARTY

Characterizing Macropores

Preferential movement of surface applied chemicals to the groundwater has resulted in a great need to physically model the movement of water into and through the soil media. Knowledge of the matrix and macropore saturated hydraulic conductivity is critical to describing these field scale processes. Utilizing fractal principles methods were developed to describe the size and distribution of macropores. Using the macropore characteristics the Marshall saturated hydraulic conductivity equation was modified to predict macropore saturated hydraulic conductivity based on soil properties. This new development enables the domain concept for modeling both macropore and matrix flow in soils to be used; thus, allowing the identification of potential pollutant paths and the assessment of agricultural practices on these paths.

CRIS 1270-13000-005-00D
DR. RAWLS

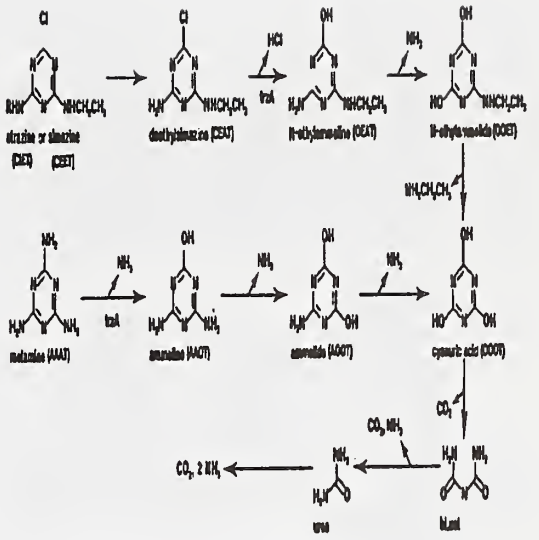
Taurocholate Potentiantes the Mutagenicity of Some Pesticides

There is considerable evidence to suggest that the biological effects of environmental chemicals on man may be modulated by diet or diet-related lifestyles. Since diets high in fat induce an increase in secretion of bile salts (tauocholate) and since high-fat diets are associated with an increased risk of cancer, we examined the effect of taurocholate on the mutagenicity of a select number of chemicals. Sodium tauocholate potentiates the mutagenicity of 4-nitroquinoline oxide, atrazine, acifluorfen, alachlor, and aldicarb as determined by the SOS Microplate Assay. Bile salt-dependent mutagenicity of chemicals in ground water is an important new finding and may be important determinant of the health effects (genotoxicity) of environmental chemicals.

CRIS 0500-00032-027-00D
DR. NAIR

Characterization of a New S-Triazine Degradation Enzyme

The widespread use and relative persistence of *s*-triazine compounds such as atrazine and simazine have lead to increasing concern about environmental contamination by these compounds. Metabolism of these agrochemicals by soil microorganisms offers one means by which these compounds



may be removed from contaminated soils before they affect groundwater. Although few bacterial strains have been identified that are capable of transforming substituted *s*-triazines, one strain of *Rhodococcus corallinus* possesses a hydrolase activity that is responsible for the dechlorination of the triazine compounds deethylsimazine and deethylatrazine. The enzyme responsible for this activity was purified and was shown to be composed of four identical subunits of 50,000 daltons. Kinetic experiments revealed that the purified enzyme is also capable of deaminating two structurally related *s*-triazine compounds as well as several pyrimidine compounds. The triazine herbicides atrazine and simazine inhibit the hydrolytic activities of the enzyme but are not substrates. Induction experiments demonstrate that triazine hydrolytic activity

is inducible and that this activity rises approximately twenty-fold during induction. The broad substrate specificity and stability of this enzyme make it an ideal candidate for further manipulation to degrade *s*-triazines in contaminated soils or water.

CRIS 1270-12130-005-00D
DR. MULBRY

Calibration of TDR Probes by Numerical Simulation of Wave Propagation

Measurement of soil water content is essential in water quality studies. Time domain reflectometers (TDR) can be used to make accurate and rapid measurements of water content in soils. The parameter required to obtain soil water content from a TDR wave trace is a function of the distance between the reflection from the handle and the reflection from the end of the TDR probe. Computer programs are available to automatically calculate this distance. The results of such programs may be unreliable when the probes are very short or water content in the soil varies along the length of the probe. In this study, propagation of a signal from a TDR along the cable, handle and probe was simulated by summing incident and reflected voltage pulses. The parameters, which are impedances and dielectric constants of the probe components and soil, are fit by using a non-linear optimization method. The TDR probe is first characterized by determining the impedance and dielectric constant of the handle from TDR traces in air and water, where the dielectric constant of the material surrounding the probe rods is known. The dielectric constant of soil with water can then be determined by fitting the reflected signal from the probe rods. In order to model the waveform accurately, the rise-time of the TDR must also be included in the calculations. Dielectric constants of soils at various moisture contents obtained from the numerical simulations were similar to those measured directly from the trace.

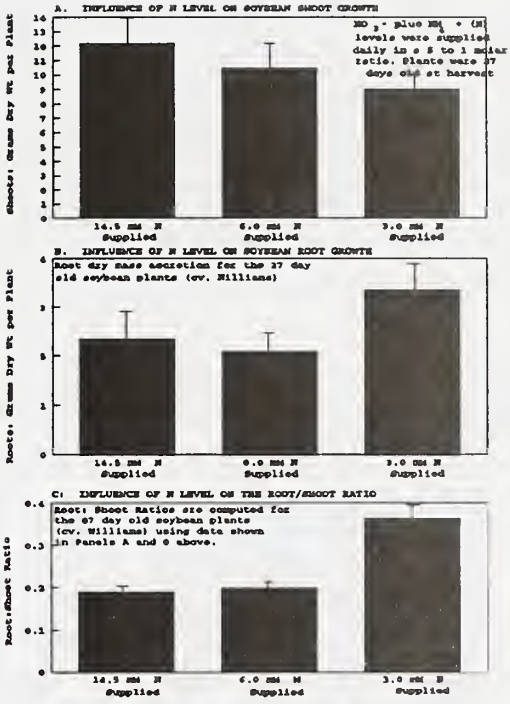
CRIS 0500-00032-030-00D
DRS. TIMLIN/PACHEPSKY

Genotoxicity of Soil Leachates, Captan, and Phenolic Compounds

Water leachates from three soils: forest, pasture, and conventional tillage were compared for genotoxicity as determined by the SOS microplate assay (SOSMA) and for total organic carbon content (TOC). These extracts were approx. 25-30x's as active as background. TOC of the samples were 12-20 ppm. Previously groundwater extracts were found to be active up to 2x's background and carbon content of 1-2 ppm. Captan demonstrated genotoxic activity in the SOSMA, however, this level was reduced in the presence of phenolic compounds. The reduced genotoxicity was due

to a reduction in bacterial activity. The phenolics did not show genotoxic activity. These results have strong implications regarding the mutagenic/genotoxic assaying of environmental samples in which these ubiquitous phenolic compounds may be present, in that, false measurements of activity are possible. Also it was found that captan preferentially causes more adenine-thymine base mutations by using a series of E. coli strains, CL101P-CL106P. This is unusual because most mutagenic pesticides cause guanine-cytosine base mutations.

CRIS 0500-00038-007-00D
DR. PFEIL/RICE



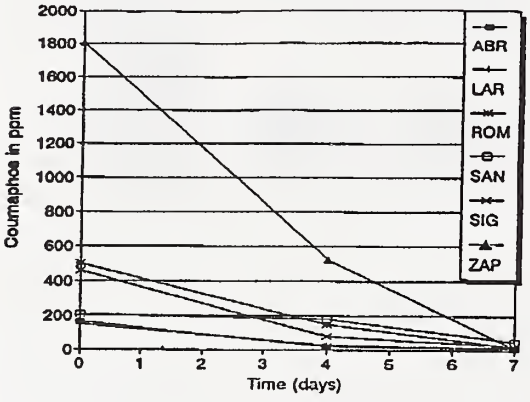
Influence of Mild Nitrogen Limitation on Soybean Plant Photosynthesis and Root Growth

A continuing problem in the world environment is the over use by humans of inorganic nitrogen (N) fertilizers; leaching of nitrates into the ground waters ultimately leads to severe limitations in aquatic agriculture and toxicity to humans. At Beltsville, current research efforts are focused on elucidation of mechanisms by which crop plants tolerate nitrogen stress. Moderate N limitations (3 to 6 mM NO_3^- plus NH_4^+) during vegetative growth of non-N_2 fixing soybeans resulted in an approximate 25% inhibition of shoot mass accretion. Although shoot growth and leaf chlorophyll were diminished in N limited soybeans, the conservation of leaf chloroplast photosystems and electron transport components, as well as the maintenance of near normal CO_2 assimilatory capacity, supported continued productivity. Further, N limited plants maintained the same or slightly greater root mass that did N sufficient plants. It currently is hypothesized that during N limitation, maintenance of root mass affords N limited plants the ability to continue to compete for available soil nitrogen as well as water. This study, and similar studies for other plants reported in the current literature, indicate that plants with harvestable below ground organs, e.g. potato tubers, may be more productive with levels of N fertilizer

which are slightly limiting to shoot growth. This information should aid agronomists and soil scientists in recommending to crop growers more conservative N fertilization programs.

CRIS 1270-21000-014-00D
DR. ROBINSON

Biodegradation of an Organophosphate Insecticide in Contaminated Soils



Degradation of coumaphos from contaminated soils from dip vat disposal pits. Soil samples were collected from disposal pits at the following APHIS vats in Texas: ABR, Abrams; LAR, Laredo; ROM, Roma; SAN, San Andreas; SIG, San Ignacio; ZAP, Zapata.

The Tick Eradication Program administered by the USDA's Animal and Plant Health Inspection Service (APHIS) is designed to prevent the re-introduction of the Cattle Fever virus into the United States. The primary effort in this program is the use of a series of dipping vats containing the organophosphate insecticide coumaphos that are placed at U.S.-Mexican border crossing points and within a quarantine zone in south Texas. Cattle imported from Mexico or from within the quarantine area must be dipped in these vats before being shipped to other areas within the U.S. As a consequence of these operations, soils in dip disposal areas are contaminated with very high concentrations of coumaphos. In this study, scientists determined the effectiveness of biodegradation processes to detoxify these coumaphos contaminated soils. In six of eight soil samples from pesticide disposal areas, indigenous microorganisms rapidly degraded coumaphos in soil slurries. In the other two samples, coumaphos was resistant to degradation even when known coumaphos degrading bacteria were added. A variety of techniques are being developed to treat these recalcitrant soils. The adaptation of biodegradation processes to treat contaminated soils offers an economical means to prevent contamination of groundwater.

CRIS 0500-00026-034-00D
DRS. MULBRY/KARNS

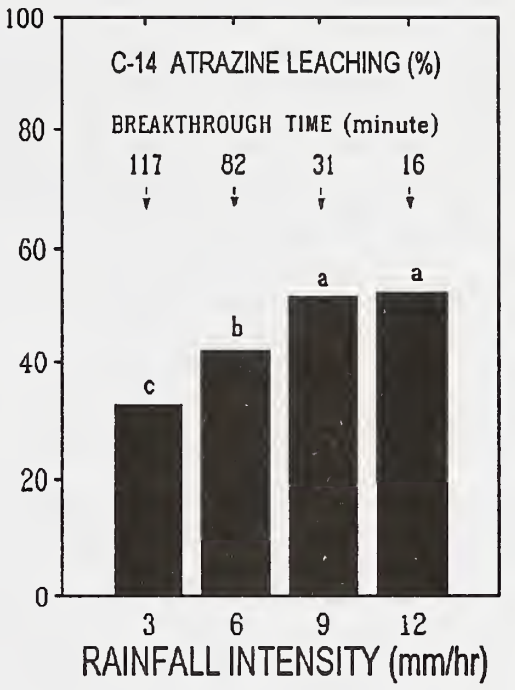
Complete Decontamination of Atrazine Laden Waste Achieved via Oxidative/Microbial Process

Ozonation followed by biomineralization has been shown in laboratory studies to effectively decontaminate aqueous solutions of pesticides (e.g. atrazine). The complete mineralization of the final ozonation product of atrazine (CAAT) was carried out using an organism isolated for its ability to tolerate

field conditions (DRS-1). Prototype units were fabricated from readily available materials and consisted of an ozonation reactor, equipped with ozone monitor and flow controllers to quantify efficiency, an ozone kill unit to destroy residual ozone in the effluent gases, and two vessels for optimal biological treatment. Results from test runs revealed that ozonation efficiency was enhanced by the injection recirculating system, however, efficiency was less than theoretical due to the recirculation of the head space gases. The ozonation products were readily mineralized by DRS-1 when organisms were attached to a celite solid support, whereas, only partial mineralization occurred when a zeolite solid support was used in the bioreactor. Further testing showed that while this matrix could modulate pH changes more effectively than the celite, it also removed divalent cations from solution, thereby limiting microbial growth and thus metabolism of atrazine degradation products. The results of this research will provide scientists, action agencies and industries with a framework for alternative strategies to remediate pesticide wastes.

CRIS 1270-12130-006-00D
0500-00026-014-00D
DRS. HAPEMAN, SHELTON, KARNS

Impact of Rainfall Intensity and Crop Residue on Atrazine Leaching



The effect of rainfall intensity and vegetative cover on pesticide leaching is not well understood, particularly under conservation tillage. Undisturbed soil cores taken from the surface horizon of a NT field were treated with atrazine and subjected to simulated rainfall at 3 to 12 mm/h. The crop residue on the surface of another set to soil cores was adjusted from 0 to 100% of average field levels, treated with atrazine and subjected to simulated rainfall at 9 mm/h. Increasing rainfall intensity increased total amount of atrazine leached; initial rate of leaching was higher at the higher rainfall intensities. Increasing amount of crop residue decreased atrazine

leaching by 25 to 37% compared to no crop residue; freshly harvested vegetation decreased leaching 20% more than dead crop residue. Results are useful for pesticide leaching models and crop residue data indicate that amount of dead and living vegetation on soil surface at spraying time may significantly affect pesticide leaching potential.

CRIS 0500-00032-004-00D
DRS. ISENSEE/SIGUA

Nitrogen Soil Test Evaluated

Residents of the Mid-atlantic region are concerned about nitrate pollution of groundwater and the Chesapeake Bay. A basic tool to increase nitrogen (N) use efficiency is a N soil test. A N soil test for corn was evaluated in Maryland which measures the nitrate N concentration in the top foot of soil when the corn is 6-12 inches tall. The test was evaluated on research farm experiments over a wide range of soils and over several growing seasons. These tests studied the effects of tillage, applications of manure or composted sludge, winter cover crops, and applications of fertilizer N on soil nitrate-N contents and corn grain yields. The results show that soil N test can successfully identified N sufficient sites. Nitrogen sufficient sites contained greater than 22 ppm nitrate-N and were usually associated with previous inputs of manure or composted sludge, or had grown legume cover crops. The accuracy of the test was not affected by tillage practices. This soil N test is most useful for manured fields where uncertainties in application rates and N losses make N management very difficult. This test is being used by Maryland extension agents, nutrient management consultants, and farmers to identify N sufficient sites and conserve fertilizer N and reduce nitrate losses to groundwater and the Chesapeake Bay.

CRIS 1270-12130-004-00D
DR. MEISINGER

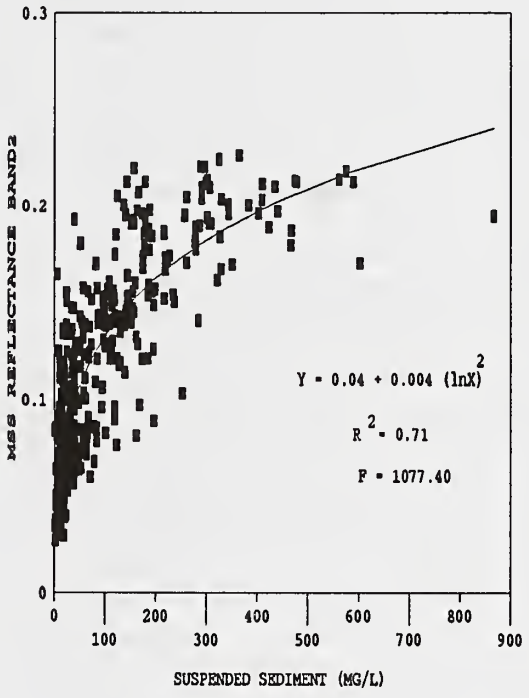
ARS Pesticide Properties Database (ARS-PPD)

The ARS-PPD is a compendium of chemical and physical properties of common pesticides. The pesticides included, used presently and in the recent past, have the potential to contaminate water supplies. The properties listed include solubility, vapor pressure, sorption coefficient field dissipation half-life and about 12 other parameters selected to provide an insight for modelers into the likelihood of well-water and run-off pollution. This has been an ongoing project at Beltsville since 1987. The ARS-PPD functions as a primary source of information for the Soil Conservation Service and other government agencies. The work over the past year has been to appreciably expand the data fields for our current list of 230 pesticides as a result of close cooperation with the pesticide manufacturers via the National

Agricultural Chemicals Association. This work has been facilitated by the efforts of Dr. Morton Beroza, who has been associated with the Systems Research Laboratory on a consulting basis. Dr. Beroza also has tabulated a list of selected values which will be of particular use for modelers. We expect that the ARS-PPD will be on-line shortly.

CRIS 0500-00026-003-00D
DRS. HERNER/ACOCK

Remote Sensing of Surface Water Quality



While broad band spectral sensors aboard satellites can provide valuable data about sediments suspended in surface waters; monitoring chlorophyll using these sensors in waters dominated by suspended sediments has been questioned. Radiance and reflectance calculated from the 4 MSS bands increased as a function of increasing concentrations of suspended sediment. Radiance and reflectance calculated from the 4 MSS bands was negatively related to the concentration of chlorophyll-a; however, no significant pattern of decrease related to the concentration of chlorophyll-a and MSS data could be determined. This study indicates that the measurement of chlorophyll-a with broad band (100 nanometer) MSS data in waters dominated by suspended sediments will not be effective since the detection of the increased absorption or scattering of radiation due to increasing chlorophyll-a is masked by the spectral scattering due to suspended sediments. Broad band spectral sensors aboard satellites will provide limited or meaningless information on chlorophyll in waters dominated by suspended sediment. In order to quantitatively determine chlorophyll by remote sensing in suspended sediment dominated systems high spectral resolution information (10 to 15 nm band widths) at approximately 675 and 705 nanometers (nm) will be required.

CRIS 1270-1300-005-00D
DR. RITCHIE

Water Quality Monitoring Fish Liver Sentinels Using MRI/MRS

Water quality studies continue at BARC using magnetic

resonance imaging (MRI)and spectroscopy (MRS). The *in vivo* and *in vitro* MRI/MRS procedures show a measure of success that is encouraging. Hepatocarcinomas, eosinophilic foci, basophilic foci and fluid-filled cysts have been delineated by displaying the data in a magnetic resonance relaxation map form and confirmed by histology. This approach is important to build a data base that establishes a correspondence between a MRI/MRS data and established pathologies for a given water pollutant. The ultimate objective is to use the MRI/MRS approach to determine the early liver tissue response to a particular pollutant or metabolic product (xenobiotic).

CRIS 0500-00038-007-00D
DR. GASSNER

NUMEX: A Nutrient Management System

The most immediate way of reducing water pollution by agricultural chemicals is to advise farmers what we know already empirically about preventing pollution. NUMEX is a combined expert system and laboratory information system for soil testing laboratories that makes recommendations to the farmer about the nutrients to apply in order to feed the crop, and how to apply them without contaminating surface and groundwater. First developed for Maryland, NUMEX has now been adapted for use in Nebraska and Iowa by encoding decision making rules used by experts in each of those states. Documentation and users guides have been written and the code delivered to the soil testing laboratories. The recommendations of NUMEX will be mailed out to farmers as part of their soil test reports, and, when the expert knowledge is applied, there should be a significant reduction in nutrients leaching into groundwater.

CRIS 0500-00032-019-00D
DR. LEMMON

2DSOIL - A New Simulator of Soil and Root Processes

Most of the models currently used to simulate the movement of agricultural chemicals through the soil are one-dimensional and fairly simple. There are clear differences in water and solute movement under rows and between those rows. Our objective was to develop a comprehensive 2-D model of soil processes and root growth and link it to some of the best crop models available. After acquiring SWMS_2D from the ARS Salinity Lab, the model was recast in modular form and modules for root growth, root water uptake and gaseous diffusion were added. The code was modified to allow for the movement of several solutes simultaneously. The new model, 2DSOIL, was documented and released to interested researchers. 2DSOIL added to a crop model will give us a research tool to improve our

management of agricultural chemicals.

CRIS 0500-00032-030-00D
DRS. TIMLIN/PACHEPSKY

Variation in Denitrification in Riparian Zones

Two cluster-well field experiments were conducted in 1992 to develop new field techniques for assessing the activity and potential for riparian areas to remove nitrates from shallow groundwater. A major observation was that the nitrate injected into laterally flowing shallow groundwater moved i) without being degraded or transformed in the absence of added carbon substrate, but ii) was quickly denitrified when glucose-C was added at the same molar concentrations as the nitrate-N. This research shows that even though the potential for denitrification may exist in riparian areas, the lack of an available carbon energy source can result in very little actual transformations of nitrate.

CRIS 1270-13000-003-00D
DR. STARR.

The Spatial and Temporal Dynamics of Water in Soil Planted to Soybean

There is only a small amount of information available concerning the spatial and temporal dynamics of soil water in a soybean crop over short time and distance scales. This information is important to evaluate the effects of plant water uptake on solute transport. The objective of this study was to obtain continuous soil water contents over relatively short time intervals in soybean to use to test the model 2DSOIL. TDR (time domain reflectometry) probes were installed in six soybean field plots in row and inter-row zones and four soil depths. Replicated probes were installed in two of the plots. TDR measurements were collected at one hour intervals using automated instruments. The data show that row-interrow differences in water uptake are very strong when the plants are relatively small. The soil water measuring method is sensitive enough to show water uptake changes during the day in response to changes in light intensity. Infiltration by rainfall also varied spatially and appeared to be dependent on rain intensity. These data will be useful to test the model 2DSOIL.

CRIS 0500-00032-030-00D
DRS. TIMLIN/REDDY/PACHEPSKY

Temporal Variation of Soil Properties that Control Leaching

To measure the temporal variation of soil properties that control leaching at a site that is incrementally changed from plow-tillage to no-tillage corn. New field studies were initiated in 1993, as a baseline year with 100% plow-tillage. Site characterization studies were

conducted for both *static* and temporally varying soil properties. The initial soil properties of interest include infiltration, macroporosity, shallow bulk density, and leaching characteristics. Five sets of infiltration measurements were made at 0-, 3-, 6-, and 10-cm tensions from June through November. Preliminary results show large temporal changes in infiltration, with between-row infiltrations generally about twice that of in-row infiltrations. This research will provide quantitative information necessary for inputs to research and management nitrogen reaction and transport models.

CRIS 1270-13000-003-00D
DR. STARR

Repeated DNA-Element Associated with S-Triazine Degradation Genes

Microbial degradation plays an important role in the dissipation of pesticide molecules from the environment. Soil microbes have shown a great ability to evolve the enzymes and pathways required to degrade pesticides. Pseudomonas species strain A (NRRLB12228) is capable of completely degrading simple s-triazine compounds (chemical substituents of the herbicides atrazine, simazine, and cyanazine), utilizing them as a source of nitrogen for cell growth. Restriction endonuclease mapping of cloned DNA containing the genes which encode s-triazine degradation enzymes in strain A revealed the presence of a repeated DNA element around which a high degree of DNA recombination seems to be occurring. The nucleotide sequence of this element was determined and compared to sequences in the GENBANK database. These examinations suggest that this repeated DNA element is a new bacterial insertion element. Such elements are known components of bacterial transposons or 'jumping genes' and may play a key role in the evolution and spread of pesticide degradation traits in soil microbes.

CRIS 1270-12130-005-00D
DR. KARNS

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COMPARISON OF FORMATION AND BIODEGRADATION OF BROMACIL OXIDATION PRODUCTS IN AQUEOUS SOLUTIONS

ACHER, A; AVNI, A; HAPEMAN, C; WATERS, R; SHELTON, D; MULDOON, M; LUSBY, W

Interpretive Summary: Bromacil, a non-selective pesticide which inhibits photosynthesis and is used for general weed control, was used in this study. The ultimate goal of this research was to develop methods for chemical and biological remediation of bromacil laden wastes. Three different methods, ozonation, UV-irradiation and sunlight sensitized irradiation were used for its oxidation. The formation of oxidation products was followed and the products were isolated and identified. The different reaction mixtures obtained after the oxidation of bromacil were submitted to biodegradation by soil, activated sludge and Klebsiella terragena strain. Phytotoxicity assay were also carried out using a plant sensitive to bromacil (Nicotiana tabacum seedlings). The results of this study demonstrate that oxidation of bromacil in water solution brings about the formation of biodegradable and nontoxic materials. Using such methods the risk of soil and water pollution by pesticides will be reduced.

Technical Abstract: A comparative study of several oxidation methods of bromacil aqueous solutions (< 600 mg/L) was conducted as part of a series of investigations concerning the chemical and biological remediation of pesticide laden wastes. Ozonation, UV-photolysis at 254 nm and sensitized solar photodegradation were examined. The oxidation products were isolated and the structures elucidated from mass spectra (CI and EI), various 13-C and 1-H NMR techniques, and other chemical methods. Three main bromacil ozonation products identified were: 3-sec-butyl-5-acetyl-5-hydroxyhydantoin (II,ca.5%), 3-sec-butylparabanic acid (III, ca. 20%), 3-sec-butyl-5, 5-dibromo-6-methyl-6-hydroxyuracil (IV,ca. 5%) which was also synthesized via hydrobromination of bromacil;a fourth product(VII) was obtained in a minute amount, but was not identified. Despite the diversity of the oxidation methods used, the same or chemically related products were formed, suggesting similarity in product formation pathways. The biodegradation (mineralization) assay of 14-C-bromacil treated solutions was investigated using soil, activated sludge or a pure culture of Klebsiella terragena (DRS-I); they indicated that the irradiated solutions were more biodegradable than ozonated solutions, although all treated solutions were biodegradable as compared with the non-biodegradable parent material. Phytotoxicity bioassays, using Nicotiana tabacum seedlings, showed a very significant decrease in the toxicity of the treated solutions.

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CLIMATE CHANGE IN AGRICULTURE

ACOCK, B

Interpretive Summary: Since the Industrial Revolution, the burning of fossil fuels (coal, oil, and gas) has caused a steady increase in the carbon dioxide concentration ([CO2]) of the Earth's atmosphere. There is growing concern that this increasing concentration of carbon dioxide will trap more energy from the sun, cause global climate change, and disrupt agriculture. However, because farmers have a range of possible responses to climate change, and plants respond positively to increasing [CO2], crop yields are generally expected to rise as climate changes. To aid farmers, agricultural researchers are preparing for climate change. Mathematical models of crop growth and development are being used to predict how yields will change. New cultivars, practices, and machines are being developed. Farmers have changed their management practices to meet past agricultural challenges, and there is every reason to believe they will adapt to future changes.

Technical Abstract: The burning of fossil fuels has caused a steady increase in the carbon dioxide concentration ([CO2]) of the Earth's atmosphere since the Industrial Revolution. In the mid-19th century levels of [CO2] were approximately 270 vpm (parts per million by volume). By 1993 these levels had increased to approximately 350 vpm. there is growing concern that the increasing concentration of atmospheric carbon dioxide will trap more energy from the sun, cause global climate change, and disrupt agriculture. Most scientists believe the Earth will get warmer as CO2 and other radiatively active gases accumulate, but there is less agreement on where and how much of a temperature increase will occur. All we can say with conviction is that the Earth's mean air temperature will probably increase by 2-6 deg C, with most of the temperature increase occurring at the poles. In the future farmers will have a range of possible responses to this climate change. Because of this flexibility, and because plants respond positively to increasing [CO2], crop yields are generally expected to rise as climate changes. To aid farmers, agricultural researchers are preparing for climate change. Mathematical models of crop growth and development are being used to predict how yields will change. New cultivars, practices, and machines are being developed. Farmers have changed their management practices to meet past agricultural challenges, and there is every reason to believe they will adapt to future changes.

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MODELING APPROACHES FOR PREDICTING CROP ECOSYSTEM RESPONSES TO CLIMATE CHANGE

ACOCK, BASIL; ACOCK, MARY C

Interpretive Summary: Climate change will result in combinations of soil, climate, and carbon dioxide concentration [CO2] that have not been experienced previously. The only realistic awe of predicting how crop ecosystems will change, is to simulate future conditions using mechanistic crop and climate models. These models all have known defects so only give a crude indication of what might happen. Also, farmers and agronomists have a long record of adapting crop ecosystems to changing conditions. There is a wide range of genetic material in the available crop species and cultivars that can fit almost any ecological niche. The farmer can also change his management practices such as planting and harvesting date, plant population density, fertilization and irrigation. Looking at the available germplasm from a modelers point of view, we can identify differences in how phenology and photosynthesis, or dry weight gain, respond to temperature and daylength. We can also identify optimum temperature ranges and extremes which will destroy a crop. This information is not readily available but should become part of the specification of every genotype. Given this information, it would be easier to help farmers choose the correct crop cultivar and management practices for any new climatic conditions.

Technical Abstract: The gradual accumulation of carbon dioxide and other gases in the atmosphere is expected to cause climate change. This will result in combinations of soil, climate and carbon dioxide concentration [CO2] that have not been experienced previously. Crop models are the only realistic tools available for predicting how yields might change. Since the models will be used to extrapolate beyond the range of existing databases they must be mechanistic. They must also mimic crop responses to a wide range of temperatures and to [CO2], especially the long-term response of stomata to elevated [CO2] and the resulting water use by the crop. However, even with adequate models it is not enough to predict crop yields assuming that everything except weather and [CO2] will remain the same. Farmers and agronomists have a long record of adapting crop ecosystems to changing conditions. In some locations, climate change will lengthen the growing season; in others it will shorten the season by virtue of high summer temperatures or drought. More fertilizer will be needed to take full advantage of increased photosynthesis in high [CO2]. The farmer will respond by changing planting date, planting density, fertilizer application rate, cultivar and even species. Predictions of crop yield in a future climate must assume that the producer will optimize his management practices for the new environment.

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DETERMINING SOIL HYDRAULIC PROPERTIES AND THEIR FIELD VARIABILITY FROM SIMPLER MEASUREMENTS

AHUJA, L R; RAWLS, W J; NIELSEN, D R

Interpretive Summary: Modeling the field soil water storage and water quality requires knowledge of soil hydraulic conductivity as a function of soil water content, and soil water retention at different suctions. Standard methods for measuring these basic soil hydraulic properties in the laboratory and field are time-consuming, tedious and expensive, especially since a large number of measurements are required to characterize the combined effects of inherent and management-induced spatial variability of these properties in a field. Innovative approaches that require less time and effort are the subject of this invited review and analyses. For both water retention and hydraulic conductivity properties, the estimations derived from soil bulk density and one-third bar (field capacity) water storage value, are shown to provide adequate accuracy for most soils. The temporal changes in properties brought about by tillage and cropping practices can also be approximated by these methods. These methods, developed by the authors over the past several years, have been used in the ARS Root Zone Water Quality Model.

Technical Abstract: This invited chapter presents a summary of recently proposed methodology for determining soil hydraulic properties using simpler measurements and less data. For water retention, the methods include estimation from soil composition and bulk density using regression equations, and the more recent scaling approaches using soil bulk density and -33-kPa (one-third bar) or -10-kPa soil water content. For the important property of saturated hydraulic conductivity, a major new development is its estimation from effective porosity, obtained from bulk density and -33-kPa soil water content, and from the pore-size distribution based on further development of the Marshall (1958) approach. The contribution of macropores to this conductivity is also addressed. For unsaturated hydraulic conductivity, the methods include the simplified field measurement methods, such as the unit-hydraulic gradient approach and a simplified functions techniques involving only field tensiometric data, as well as the estimation of K(h) from water retention data and saturated value of K(h). The temporal changes in water retention and K(h) brought about by management practices of tillage, no-tillage, residue, and cropping can be important, but only briefly addressed because of limited knowledge of these changes available at present.

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NITROGEN REQUIREMENTS FOR CORN

BUNDY, LARRY G; BANDEL, VERNON A; MEISINGER, JOHN J

Interpretive Summary: It is essential to make accurate corn fertilizer nitrogen (N) recommendations to ensure farm profitability and to minimize environmental concerns. Corn takes up N from fertilizers, manure, previous legume crops, residual nitrate, and soil organic matter. Corn fertilizer N needs should first consider the N required by the crop. This is usually figured from the expected yield or yield goal, which can be calculated from the 3-5 year average yields for a field. A factor of 1.2 lb N/bu is then multiplied by the expected yield to estimate the crop N need, but recent research suggests that 1.0 lb N/bu is more appropriate in several states. The non-fertilizer N sources of a site must also be taken into account to optimize N recommendations, these include: manure applications, previous legume crops, soil organic matter, and residual nitrate. These can be assessed through manure tests, cropping histories, fertilizer replacement credits, and soil nitrate tests. It is not unusual to have manure or recent forage legume residues furnish most of the corn N requirement. Adjustments for non-fertilizer N sources must be subtracted from the base corn N requirement. Field soil N test calibration programs should continue to refine and improve corn N recommendations so that profitable corn production is achieved and environmental effects are minimized.

Technical Abstract: A summary was made of methods used to determine corn fertilizer N (FN) requirements. Accurate FN recommendations are essential for profitable corn production and for minimizing adverse environmental effects. Corn utilizes N from fertilizers, manure, previous legume crops, residual NO3-N and soil organic matter. Estimating the corn FN requirement first involves site- specific assessment of the N required by the crop; which is commonly based on expected yield or yield goals. A conversion factor of 1.2 lb N bu-1 of expected grain yield is widely used, but recent research suggests that 1.0 lb N bu-1 is more appropriate in several states. Realistic yield goals are essential and are best estimated using 3-5 year averages of actual yields from a field. The non-FN inputs of a site must also be taken into account to optimize FN recommendations, these include: manure applications, previous legume crops, soil organic matter, and residual NO3-N. These can be assessed through manure tests, cropping histories, fertilizer replacement credits, and soil nitrate tests. It is not unusual to have manure or recent forage legume residues furnish all, or a major portion of, the corn N requirement. Alternatively, FN recommendations can be based on N response data from representative soils. Field N test calibration programs with NO3-N monitoring should produce FN recommendation systems that give profitable corn production and minimize environmental effects.

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WINTER ANNUAL COVER CROPS FOR MARYLAND CORN PRODUCTION SYSTEMS

DECKER, A M; CLARK, A J; MEISINGER, J J; MULFORD, R F; BANDEL, V A

Interpretive Summary: Cover crops are raised between the growing seasons of normal grain or forage crops. Benefits of cover crops include: reduced soil erosion, added organic matter, improved yields of the next crop, improved water available to the next crop through mulching, added nitrogen through legume fixation, and conserve nutrients. Legumes (clovers, vetches, etc.) will add nitrogen and give good mulches, but their seed is expensive and they are slow to establish. Grasses (rye, wheat, oats, etc.) are easily and quickly established, are cheap to seed, and will conserve nutrients; but often leave a nitrogen debit for the next crop. Grass-legume mixtures are a good compromise and offer benefits of each component. Timely spring killing of the cover is also important. Covers can be killed by plowing or with herbicides, but can also be grazed or harvested for forage. The spring kill date will vary with spring rainfall; in an average year most legumes should be killed in late April to early May, and grasses in early April. In dry springs these dates should be 2-3 weeks earlier. Corn should be planted 5-15 days after killing, to allow the soil to dry and warm. Specific cover crop management techniques (seeding rates, depths, kill dates, etc.) are also given. Cover crops are an under-utilized practice in Maryland which could provide important benefits to farmers, to society, and to the environment.

Technical Abstract: Cover crops are an under-utilized conservation practice. Cover crops are plants grown between periods of traditional crop production. Some benefits of cover crops include: reduce soil erosion, add organic matter, improve productivity of the next crop, improve water use efficiency, fix atmospheric N, conserve nutrients, and improve water quality. Maximum benefits are realized by matching cover crop species to the specific goal desired, to the site's soil and climate, and to the specific cropping system. Legume species can add N to the system through N fixation and increase water use efficiency through mulching, but they are slow to establish and seed is expensive. Grass species are quick to establish and will conserve nutrients, but can create a N debit for the next crop. Grass-legume mixtures can incorporate some of the benefits of both components. Covers should be seeded as soon as possible in the late summer or early fall. Spring killing can be accomplished by plowing, herbicide spraying, grazing, or harvesting for silage. The spring kill date will vary with spring rainfall patterns; in an average year most legumes should be killed in late April to early May, and in early April for most grasses. Corn should be planted 5-15 days after killing, to allow the soil to dry and warm. Management of specific cover crops (seeding rate, depth, kill dates, etc.) is discussed.

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LEGUME COVER CROP CONTRIBUTIONS TO NO-TILLAGE CORN PRODUCTION SYSTEMS

DECKER, A M; CLARK, A J; MEISINGER, J J; MULFORD, R F; MCINTOSH, M S

Interpretive Summary: Farmers and farm advisors need information on optimum fertilizer nitrogen levels for corn following winter covers because covers can supply nitrogen and conserve moisture for the next crop. Research in the Coastal Plain and Piedmont regions of Maryland evaluated fertilizer nitrogen rates and winter cover crops of hairy vetch, Austrian winter pea, crimson clover, and wheat on no-tillage corn production. Cover crop dry matter and N content were measured, as well as corn N uptake, grain yield and silage yield. Cover crop N contents (in lb N/acre) in the Coastal Plain averaged about 185 for hairy vetch, 160 for peas, 150 for crimson clover, and 35 for wheat. Corresponding values in the Piedmont were about 40% lower due to shorter winter growing seasons. With no fertilizer nitrogen corn grain yields were higher following legume covers than after no-cover and were lowest following wheat. Corn grain yields were about 10-15% greater after fertilized legume covers than after a fertilized wheat cover or no-cover. The fertilizer nitrogen needs without a cover crop averaged about 120 and 65 lb N/acre in the Coastal Plain and Piedmont regions, respectively. With a grass cover crop the average fertilizer nitrogen need increased about 10-25 lb N/acre, while after a legume cover it decreased about 20-65 lb N/acre. These results will be very useful to farmers and farm advisors because they demonstrate the nitrogen supplying ability and water conservation benefits of winter cover crops. This information should speed the adoption of winter cover cropping into modern conservation tillage cropping systems.

Technical Abstract: Winter cover crops can supply nitrogen (N) and conserve moisture for the next crop. A three-year study was conducted in the Coastal Plain and Piedmont regions of Maryland to evaluate the effect of winter cover crops of hairy vetch (Vicia villosa Roth), Austrian winter pea (Pisum sativa (L) Poir), crimson clover (Trifolium incarnatum L.) and wheat (Triticum aestivum L.) on no-tillage corn (Zea maize L.) production. These studies evaluated cover crops and four FN rates. Crop parameters studied were: cover crop N content, corn N uptake, and corn grain and silage yields. Nitrogen contained in the Coastal Plain cover crops averaged about 205, 180, 170, and 40 kg N ha-1 for hairy vetch, peas, crimson clover, and wheat; respectively. Corresponding Piedmont values were about 40% lower due to a shorter growing season. With no FN corn grain yields were higher following legume covers than after no-cover and were lowest following wheat. There was a synergistic response between legume cover crops and FN, especially with hairy vetch, with the greatest corn yields occurring after legumes fertilized with 90-135 kg N ha-1. Because of the difference in maximum yields the FN needed to achieve optimum yields was not related to cover crop N content. The FN needs without a cover crop averaged about 75 kg N ha-1 in the Piedmont and about 135 kg N ha-1 in the Coastal Plains. Greater efforts should be made to incorporate winter cover crops into modern cropping systems.

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PREDICTING N FERTILIZER NEEDS FOR CORN IN HUMID REGIONS: ADVANCES IN THE MID-ATLANTIC STATES

FOX, R M; MEISINGER, J J; SIMS, T; PIEKIELEK, W P

Interpretive Summary: Residents of the Mid-Atlantic region are concerned about nitrate pollution of groundwater and the Chesapeake Bay. Agricultural researchers in Pennsylvania, Maryland, and Delaware have evaluated 221 field trials which investigated the applicability of a soil nitrate test for corn which should reduce nitrate leaching from agriculture. The test measures the nitrate concentration in the top foot of soil when the corn is about 12 inches tall, which is about two weeks before normal sidedress fertilizer nitrogen is applied. In 82% of the cases the test successfully identified nitrogen sufficient sites, that is, identified sites which need no additional fertilizer. The accuracy of the test was not affected by tillage practices. The nitrate test is most useful for manured fields where uncertainties in application rates and N losses make nitrogen management very difficult. This test will help extension agents, nutrient management consultants, and farmers identify nitrogen sufficient sites and thereby conserve fertilizer nitrogen and reduce nitrate losses to groundwater and the Chesapeake Bay.

Technical Abstract: Improving nitrogen fertilizer use efficiency is an important task for agricultural scientists. The pre-sidedress nitrate test (PSNT) is one tool to improve N fertilizer use efficiency; it measures the soil NO3-N concentration in the surface 30 cm of soil when the corn plants are 30 cm tall. A combined analysis of PSNT data from 221 field trials in Pennsylvania, Maryland, and Delaware was conducted to evaluate the over- all usefulness of the PSNT as a predictor of fertilizer N response. The evaluation showed that PSNT as a predictor of fertilizer N response. The evaluation showed that PSNT values greater than 22 mg N kg-1 were associated with N sufficiency. The PSNT was a good predictor of N sufficiency, with non-responding sites correctly identified 82% of the time. However, the PSNT was not a good predictor of relative grain yields for sites with less than 22 mg N kg-1, especially if the site was first- year corn after a forage legume. The PSNT seems to be best suited for manured fields where uncertainties in manure loading rates and N losses due to ammonia volatilization and denitrification are highly variable. Tillage practice has little or no effect on the PSNT accuracy. Use of the PSNT should reduce the practice of applying "insurance N" which should improve fertilizer N use efficiency and reduce NO3-N contamination of our water resources.

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COMPARISON OF FORMATION AND BIODEGRADATION OF BROMACIL OXIDATION PRODUCTS IN AQUEOUS SOLUTIONS POSITIONAL AND ANISOTROPIC CHANGES DURING DEVELOPMENT OF THE DESERT LOCUST

GASSNER, G; SCHMIDT, W F

Interpretive Summary: Nuclear magnetic resonance (NMR) can provide spatial information on live biological structure. This study demonstrates that the left/right and up/down asymmetries of a locust embryo can be observed during development. The patterns of asymmetry are disrupted during abnormal development and can be monitored by NMR signals. These finding have significance in relation to magnetic resonance imaging (MRI). Structural symmetries must be considered when MRI spatial assignments are made.

Technical Abstract: Both microscopy and nuclear magnetic resonance (NMR) give consistent results on the asymmetrical relationships observed during embryonic development of the desert locust. Microscopy shows developmental, positional and morphological changes while NMR shows magnetic anisotropic effects. Changes in position of anatomical features correlate with chemical shift anisotropies.

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RELATIONSHIPS OF MAGNETIC RESONANCE T2 RELAXATION AND SPIN DENSITIES TO FIXATION IN THE DIAGNOSIS OF LIVER LESIONS IN THE MUMMICHOG

GASSNER, G; VOGELBEIN, W; LINE, M

Interpretive Summary: Magnetic resonance (MR) and light microscope (LM) studies were combined to examine changes in fish livers following environmental insults. This approach was chosen to eliminate the need for complex animal support systems and gain improved spatial resolution. The results show that cytological features and MR data can be related. Now, it is clear that the vast library of histological methods can be explored for future MR and LM complimentary options.

Technical Abstract: Combined magnetic resonance (MR) and light microscopy (LM) studies of cytologically fixed mummichog livers were carried out to detect anomalies. The livers were fixed using three established solutions: Bouin's, Karnovsky's and neutral buffered formalin. MR images of the fixed excised livers were recorded. Following the MR procedure, the livers were sectioned and stained for LM. The MR and LM images of each liver specimen were superimposed by light projection. The superimposition made it possible to bring the MR and LM features into register for comparison. The eosinophilic stained liver lesions fixed in Bouin's solution gave the clearest indication of MR and LM feature coincidence. The MR image contrast coincident with eosinophilic foci was related primarily to spin density.

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IMPACT OF TILLAGE ON HERBICIDE LEACHING

GISH, T J; SHIRMOHAMMADI, A; MCKEE, L; WIENHOLD, B; VYRAVIPILLAI, R

Interpretive Summary: It is generally accepted that no-till farming practices conserve surface soil resources. However, the impact of no-till on groundwater quality is less obvious since infiltration, and subsequent leaching losses may also be greater compared to conventional tillage. This study demonstrates, on well aerated and hydrologically bounded watersheds, that no-till practices may also have a beneficial impact on groundwater quality. Herbicide levels at 1.5-1.8 m were much lower under no-till than under conventional tillage. The reduced herbicide levels under no-till was attributed to the formation of macropores were organic matter accumulates and biological activity is high. As a result, in aerated soils, no-till practices may conserve both the soil surface as well as the quality of groundwater underlying agricultural fields.

Technical Abstract: The impact of tillage practice and herbicide formulation on leachate concentration of bromide, atrazine [6-chlor-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine] and alachlor [2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl)-acetamide] below the active root zone were determined. Four adjacent watersheds (0.25 ha each), two no-till and two conventionally tilled, were instrumented with suction lysimeters between 1.5 and 1.8 m depths and sampled after each rain event >1cm. One field received herbicides as a commercial formulation and the other two received herbicides as a starch-encapsulated formulation. Bromide breakthrough curves for volume and concentration weighted field values was bimodal with respect to time. Presumably, the first pulse was due to shallow preferential transport shortly after application while the second pulse was due to the bulk movement of bromide with the moving soil solution. Over a 400 d period, alachlor rarely was detected in the solution samples, regardless of tillage practice or herbicide formulation. Atrazine was detected under both conventionally tilled watersheds, but at lower concentrations with starch-encapsulated. Essentially no herbicide was recovered under no-till, regardless of herbicide formulation. The absence of any herbicide under no-till management was attributed to the formation of stable flow channels that may also be correlated with high biological activity.

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INFLUENCE OF TILLAGE ON NITRATE LEACHING BELOW THE ROOT ZONE

GISH, T J; SHIRMOHAMMADI, A; MCKEE, L; VYRAVIPILLAI, R

Interpretive Summary: Modern agricultural practices attempt to maximize food and fibre production while minimizing detrimental environmental impact. Nitrogen, one of the most heavily used agricultural chemicals, has generated considerable concern with respect to human health. Tillage practice effects environmental fate of nitrogenous compounds by effecting how nitrogen compounds interacts with the complex hydrologic cycle. To evaluate the influence of tillage on nitrate leaching below the root zone a multidisciplinary field approach was taken. Conventional and no-till practices were monitored on hydrologically bounded watersheds. During a 521 day study, significantly lower nitrate levels were consistently observed under no-till than under conventional tillage. As a result, this data suggests that no-till practices may conserve both surface soil resources as well as the quality of groundwater underlying agricultural lands.

Technical Abstract: A field site was established in Upper Marlboro, Maryland, in 1989 to evaluate agricultural alternatives that may potentially conserve natural resources. Specifically, a 521 d field study evaluating nitrate and bromide leaching below the root zone of no-till and conventionally tilled watersheds was conducted. The watersheds (-0.25 ha each), were instrumented with suction lysimeters at 1.5-1.8 m and were sampled after each rain event >1 cm. Single annual applications of nitrogen (196 kg N ha -1) were initiated in 1989, and in 1991 bromide (80 kg Br ha -1) was added as a solute tracer. Bromide breakthrough curves were similar for both no-till and conventional tillage, each being bimodal with respect to time. Early detection of bromide indicated that at least a portion of the preferential flow was sampled. However, bromide concentrations during winter recharge suggest that much of the bromide moved uniformly through soil matrix for both tillage treatments. NO 3 -N concentrations from the lysimeters were consistently lower under no-till than under conventional tillage. Averaged NO 3 -N concentrations, over the duration of the study, were 12.35 mg L -1 for no-till and 18.45 mg L -1 under conventional tillage. Since bromide breakthrough curves indicate the interception of preferentially transported solutes and no dilution effect was observed, the reduced NO 3 -N levels under no-till management was attributed to increased immobilization and enhanced denitrification on the soil surface and in preferential flow pathways.

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FIELD-SCALE MOBILITY AND PERSISTENCE OF COMMERCIAL AND STARCH-ENCAPSULATED ATRAZINE AND ALACHLOR

GISH, T J; SHIRMOHAMMADI, A; WIENHOLD, B

Interpretive Summary: Atrazine and alachlor are two of the most widely used herbicides in modern agriculture. Unfortunately, these two herbicides are two of the most frequently observed herbicides in groundwater. To address these problems, the Agricultural Research Service has been investigating various herbicide formulations that could effect environmental impact. One developing technology involves encapsulating the herbicide not with a membrane coating, but encapsulating the pesticide in such a way that it is dispersed throughout the granule. This manuscript reports on a two-year field study showing that starch-encapsulation reduces herbicide mobility when compared to commercial formulations. By decreasing leachate losses, herbicide soil persistence increased.

Technical Abstract: Recent laboratory and small field plot studies have shown that starch-encapsulation (SE) may reduce both volatilization and leachate losses of certain pesticides relative to commercial formulation (CF). This study compares field-scale mobility and persistence of atrazine [2-chloro-4-ethylamino-6-isopropylamino-s-triazine] and alachlor [2-chloro-N-(2,6-diethylphenyl)-N-(methoxymethyl)acetamide] in both SE and CF. The field site consists of four unreplicated watersheds, approximately 0.2 ha each. Two watersheds were under no-till management; one receiving atrazine and alachlor in the SE formulation and the other receiving the herbicides in CF. The remaining two fields were under conventional tillage; one receiving SE and the other CF. Chemical movement and persistence was determined by analysis of 1.1 m soil cores for herbicides. The significantly increased persistence of SE-atrazine relative to CF-atrazine was attributed to the reduction of leachate losses. This decrease in mobility may be an indication of atrazine diffusion into the soil matrix, where it is less subject to preferential flow processes. Alachlor residue levels 1 h and 12 d post-application were significantly larger for the SE formulation than for either of the two CF formulations. This difference at early times is attributed to SE causing reduced alachlor loss during application. Unlike with atrazine, alachlor mobility was not dramatically reduced by the SE formulation.

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EFFECT OF STARCH-ENCAPSULATION ON BEHAVIOR OF ATRAZINE AND ALACHLOR

GISH, T J; WIENHOLD, B; SHIRMOHAMMADI, A

Interpretive Summary: Atrazine and alachlor are among two of the most widely used herbicides which have been frequently detected as contaminants in groundwater and in the atmosphere. As a result, USDA-ARS has been evaluating agricultural alternatives that will minimize the impact of these herbicides on the environment. Starch-encapsulation is an alternative to the present commercial formulations that modifies how the herbicides interacts with the soil environment. This manuscript discusses recent laboratory, greenhouse, and field experiments that evaluate how starch-encapsulation modifies environmental impact relative to presently available commercial formulations.

Technical Abstract: To maintain high agricultural yields, large quantities of herbicides are applied to soils each year. After application, these herbicides can impact the environment via leaching to groundwater, volatilization, and surface transport through runoff and soil erosion. The purpose of this paper is to review recent work with a developing technology, starch-encapsulation (SE). Starch-encapsulation allows for reproducible herbicide release rates from starch granules. By controlling the rate of release, herbicide behavior can be modified. The magnitude of the modification is variable, dependent on chemical characteristics of the encapsulated herbicide, granule characteristics, and the soil-water environment. Starch encapsulation has been shown to reduce cumulative volatilization losses of atrazine; reduce runoff losses of atrazine and alachlor; reduce leaching of surface applied atrazine; and increase persistence of atrazine. These results suggest that SE may be a viable way of reducing detrimental environmental affects associated with the use of agricultural pesticides.

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EXPRESSION OF ACHROMOBACTER CARBOFURAN HYDROLASE IN ESCHERICHIA COLI

HAUSCHILD, J E; FRIED, S G; KARNS, J S; TOMASEK, P H

Interpretive Summary: Carbofuran hydrolase is an enzyme that can inactivate many methylcarbamate insecticides, including carbofuran, carbaryl, and aldicarb. This enzyme was identified in the soil bacterium Achromobacter species WM111 and the gene encoding it (the mcd gene) was cloned. WM111 is a slow growing bacterium with no known mechanisms for genetic manipulation so using strains containing the cloned gene for further study of the gene or enzyme would be very convenient. However, the amount of active carbofuran hydrolase produced in strains of bacteria containing the cloned mcd gene was very low. In this study it was shown that the reason for the low amount of enzyme activity in strains of E. coli carrying the cloned mcd gene was that the bulk of the protein produced was incorporated into insoluble inclusion bodies. Reduction of the temperature at which the cells were grown from 37 to 30 degrees centigrade resulted in a higher percentage of the carbofuran hydrolase protein synthesized in its active form such that more activity was obtained at 30 degrees even though the total amount of carbofuran hydrolase protein produced was less. The orientation of the gene on the cloned DNA fragment was also established. These results will aid in efforts to produce large amount of carbofuran hydrolase for use in studies on removal of carbamate insecticides from the environment.

Technical Abstract: Carbofuran hydrolase from Achromobacter sp. strain WM111 is encoded by the plasmid-borne mcd gene. This enzyme hydrolyzes N-methylcarbamate pesticides yielding methylamine which can then be utilized as a nitrogen source by strain WM111. A 3.1 kilobase-pair (kb) Cla I-Cla I DNA fragment containing the mcd gene was cloned into the pBlueScript SKII+ vector and introduced into E. coli. E. coli clones producing carbofuran hydrolase were identified using a carbaryl/fast blue RR plate assay. Only one orientation of the cloned insert demonstrated carbofuran hydrolase activity by this assay, establishing the direction of mcd transcription. Using a xylE promoter probe vector, the region upstream of the mcd structural gene was shown to contain a promoter which functioned poorly in E. coli. Deletion of approximately 500 base pairs from the 3.1 Cla I fragment in the region 5′ to the mcd structural gene resulted in a two to four fold increase in the level of carbofuran hydrolase activity in E. coli. This increased expression of the gene resulted in the formation of inclusion bodies which limited the amount of active enzyme that could be obtained from cells grown at 37 degrees centigrade. Reduction of the growth temperature to 30 degrees reduced inclusion body formation such that a higher proportion of the enzyme was produced in its active form.

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TWO POLYPEPTIDES ASSOCIATED WITH ACHROMOBACTER CARBOFURAN HYDROLASE INTERACT TO PRODUCE THREE ACTIVE FORMS OF THE DIMERIC ENZYME

HAUSCHILD, J E; KARNS, J S; TOMASEK, P H

Interpretive Summary: The soil bacterium Achromobacter sp. strain WM111 produces an active carbofuran hydrolase that cleaves the N-methylcarbamate linkage of many insecticides including carbofuran, carbaryl, and aldicarb. When this enzyme was purified it was seen that the enzyme was made up of 2 polypeptide subunits, 1 of 72 kilodaltons (kDa) in size and the other of 77 kDa. When the mcd gene encoding carbofuran hydrolase was cloned into Pseudomonas putida it was shown that the gene resided on a 3 kilobase (kb) DNA fragment and that both the 72 and 77 kDa polypeptides were produced. This is unusual because a 3 kb DNA fragment cannot code for two polypeptides of this size (2 kb of DNA encodes a polypeptide of about 77 kDa) unless the genes share substantial overlap. This study shows that the two polypeptides are, for the most part, identical. Thus, we conclude that either the 72 kDa peptide is derived from the 77 kDa peptide by proteolytic cleavage or that there are two translation start sites on the messenger RNA transcribed from the mcd gene such that different sized peptides are made from the same in-frame reading of the mcd message. The two polypeptides can combine in all possible combinations to form 3 different sizes of the carbofuran hydrolase enzyme, all of which have activity. Two different translation start sites for one enzyme may mean that this soil bacterium has a means of regulating enzyme synthesis at the level of translation.

Technical Abstract: Achromobacter sp. strain WM111 is a soil bacterium which produces the enzyme carbofuran hydrolase. In addition to carbofuran, carbofuran hydrolase hydrolyzes other N-methylcarbamate pesticides such as carbaryl and aldicarb, allowing these compounds to be utilized as the organism's sole nitrogen source. The molecular mass of native carbofuran hydrolase is approximately 150 kilodaltons (kDa). SDS-polyacrylamide gel electrophoresis of purified carbofuran hydrolase shows the presence of two polypeptide subunits with masses of 72 and 77 kDa. Three forms of the active carbofuran hydrolase dimer were identified on native polyacrylamide gels stained for activity. These bands were excised from the gels and run on SDS denaturing polyacrylamide gels to determine the subunit associations in the three active carbofuran hydrolase holoenzymes. The three forms of the active enzyme were formed from the dimerization of all possible combinations of the two polypeptide subunits. Protease digestion of the gel purified polypeptides demonstrated that the two protein subunits were essentially identical.

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PHYSICAL AND CHEMICAL PROCESSES AFFECTING PREFERENTIAL FLOW

HELLING, C S; GISH, T J

Interpretive Summary: Evidence has mounted over the past 10-20 years linking deeper than expected leaching of some agrochemicals into soils with preferred flow pathways. One major type includes macropores - large pores, fissures, channels, or other semi-continuous voids. These may be caused biologically, following decay of roots or through burrowing of earthworms or arthropods. Alternatively, macropores may form by natural soil aggregation. Fingering of soil water is a type of preferential flow caused by wetting front instability, and is most likely to occur in coarse-textured soils, especially at textural discontinuities. Nitrate, dye tracers, and pesticides of intermediate mobility have been shown to leach preferentially. For pesticides, transport through macropores is most likely when moderate to heavy rainfall occurs soon after application. Preferential flow appears to be more likely under long-term no-till conditions than with conventional till.

Technical Abstract: Over the past 10-20 years evidence has mounted linking deeper than expected leaching of some agrochemicals into soils with preferred flow pathways. One major type includes macropores - large pores, fissures, channels, or other semi-continuous voids. These may be caused biologically, following decay of roots or through burrowing of earthworms or arthropods. Alternatively, macropores may form by natural soil aggregation. Fingering of soil water is a type of preferential flow caused by wetting front instability, and is most likely to occur in coarse-textured soils, especially at textural discontinuities. Nitrate, dye tracers, and pesticides of intermediate mobility have been shown to leach preferentially. For pesticides, transport through macropores is most likely when moderate to heavy rainfall occurs soon after application. Preferential flow appears to be more likely under long-term no-till conditions than with conventional till.

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SIMULTANEOUS NONLINEAR IRREVERSIBLE REACTION AND MOVEMENT OF SOLUTES IN SOILS

HOGARTH, W L; PARLANGE, J Y; STARR, J L

Interpretive Summary: The ability to model the simultaneous irreversible reaction and movement of nitrates and other agrochemicals in soils is important in environmental studies. This paper presents a new mathematical model for a two-substrate reaction and movement, e.g., nitrate-N and glucose-C, that enables the full range of kinetics to be explored. The model provided excellent characterization of nitrate outflow concentrations from laboratory column studies. This model will provide a more accurate mathematical tool to environmental scientists to provide initial estimates of natural reaction rate coefficients; comparison of these values under different environmental conditions; and estimates of microbially induced effects on the movement of nitrates to groundwater.

Technical Abstract: This paper presents an approximate analytical solution for a nonlinear irreversible reaction involving the movement of solute when two substrates are involved. The presence of the second substrate determines when the reaction will proceed. The implicit solution obtained enables the continuum of irreversible reactions to be explored through the Michaelis-Menten form. The effect of the second substrate being present or not at the start of the reaction is investigated. Validation of the approximate analytical solution is achieved by systematic comparison with a numerical solution. The effect of boundary conditions on the solution for a finite column is examined. With a change from aerobic to anaerobic conditions initially, the effect on the breakthrough curves and concentration profiles of having a flux-concentration inlet boundary condition with a zero-flux outlet condition for a finite column is compared with a fixed-concentration inlet condition for a semi-infinite column. The approximate solution is also applied to an experimental breakthrough curve to estimate nonlinear denitrification parameters.

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IMPACT OF TILLAGE AND RAINFALL CHARACTERISTICS ON THE TEMPORAL VARIABILITY OF ATRAZINE IN SOIL

ISENSEE, A R; SADEGHI, A M

Interpretive Summary: Conservation tillage practices have been in widespread use for 10 to 15 years, but little field data is available on how tillage effects fate and distribution of pesticides in soil, especially under differing rainfall conditions. We describe a long-term field study designed to determine the distribution of atrazine in soil following surface application to no-till (NT) and conventional-till (CT) fields relative to soil residue levels and rainfall characteristics. Crop residue and living vegetation intercepted 60 to 70% of the atrazine applied to NT plots. Most of intercepted atrazine was gradually washed off crop residue which resulted in much lower concentrations of atrazine in the surface 10 cm of soil under NT than CT. Increased leaching below 10 cm was evident under NT compared to CT (especially in two years in which a significant rain event occurred soon after application), but total amounts of atrazine recovered in the sampled profile (0 to 50 cm) was still lower under NT than CT. Rainfall timing (time after application), total amount and intensity were all important in accounting for differences in atrazine residues between years. The implication of this study is that unless a major rain occurs soon after pesticide application, NT practices will effectively reduce the amount of atrazine found in the surface 50 cm of soil compared to CT.

Technical Abstract: A field study was conducted in 1987-1991 to determine the effect of tillage practice and rainfall characteristics on the distribution of atrazine in soil. Soil samples (10 cm increments to 50 cm) and crop residue were taken at regular intervals after application each year and analyzed for atrazine. Crop residue and living vegetation on no-till (NT) plots intercepted 60 to 70% of the applied atrazine; 2.6 to 16% of the atrazine remained in crop residue 1 to 2 weeks later. The amount of atrazine recovered in soil,1 to 2 weeks post-treatment, ranged from 22 to 59% and 47 to 73% of the amount applied to NT and CT, respectively. An average of 2.6 times less atrazine was recovered in the surface 10 cm of soil under NT than under conventional-till (CT) for all samplings and years. Total amounts of atrazine in the sampled profile (10 to 50 cm depth) were also generally lower under NT than CT. More leaching below 10 cm occurred under NT than CT particularly in 1988 and 1991 when rain fell soon after application. Atrazine levels in soil between years were related to timing and amount of the first and subsequent rainfall events after application.

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IMPACT OF TILLAGE PRACTICE ON SHALLOW GROUNDWATER QUALITY

ISENSEE, A R; SADEGHI, A M

Interpretive Summary: This paper describes the effect of no-till compared to conventional-till corn production practices on the leaching of atrazine, alachlor and cyanazine to shallow groundwater over a 5.5 year period in a field site at Beltsville, MD. Samples of unconfined (<1.5 m deep) and confined (< 3 m and 4.5 to 11 m deep) groundwater were collected and analyzed for the pesticides at monthly intervals. Highest concentrations of all pesticides occurred in confined groundwater (<3 m deep) soon after application under both tillage systems. Concentrations declined to low (atrazine) or nondetectable (alachlor and cyanazine) levels within three months. Rainfall timing and amount relative to pesticide application was critical to determining the magnitude of pesticide leaching to groundwater. The highest concentrations of the study were caused by a 4.8 cm rain that began 12 hours after application in 1988. This study indicates that more pesticide leaching to shallow groundwater occurs under no-till than conventional till, but peak levels exceeded health advisory levels only once in the study and residues decreased rapidly with time. Additionally, residues in deep wells (4.5 to 11 m) remained below the detection level indicating that these pesticides had not leached to this depth after as many as ten years of continuous pesticide application.

Technical Abstract: A field experiment was established in 1986 to assess the effect of conventional and no-till cultural practices on the movement of pesticides into shallow groundwater. Groundwater was sampled from unconfined (<1.5 m deep) and confined (<3 m and 4.5 to 11 m deep) monitoring wells in 1986-1991 and sampled for atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5triazine -2,4-diamine], alachlor [2-chloro-N-(2,6-diethylphenyl)-N- (methoxymethyl)acetmide], and cyanazine [2-[[4-chloro-6- (ethylamino)-1,3,5-triazine-2-yl]amino] -2-methylpropanenitrile]. Concentrations of pesticides were cyclical; residues were highest soon after application each year and then declined, alachlor and cyanazine to nondetectable levels within 3 mo. Atrazine residues, present in confined groundwater all year, ranged in concentrations between 0.03 to 1.9 and 0.16 to 3.4 ug/L for the NT and CT plots, respectively for 53 of 56 samplings over 5.5 y. Atrazine residues under fields treated before 1986 declined from <0.5 ug/L in 1987-88 to <0.01 ug/L by 1991. Pesticide residues were higher in unconfined than confined groundwater. Amount and timing of rainfall relative to pesticide application was critically important to pesticide leaching. The highest pesticide concentrations of the 5.5 y study were caused by a prolonged rain immediately after application in 1988 with concentration spikes ca. 4 to 50X greater under no-till than conventional till plots. Results of this study suggest that preferential transport occurred.

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IMPACT OF TILLAGE PRACTICE ON RUNOFF AND PESTICIDE TRANSPORT

ISENSEE, A R; SADEGHI, A M

Interpretive Summary: Studies conducted to evaluate the effect of tillage practice on both the volume of runoff and pesticide loss in runoff have shown that no-till can either increase or decrease loss compared to conventional till. Most of those studies were conducted on small plots using rain simulators, often at high rainfall intensities. This study describes runoff and pesticide loss from relatively large no-till and conventional till plots from natural rainfall over two years. Runoff was measured, and samples were collected for atrazine, cyanazine and alachlor analyzes for 2 and 3 months after application in 1990 and 1991, respectively. Time between rainfall events was critical in controlling the amount of runoff. When rain events were more than 7 days apart, runoff was greater from no-till than conventional till.The reverse occurred when 7 or more days passed between rains. Pesticide concentrations in runoff and total loss were greatest for atrazine followed by cyanazine and alachlor. Concentrations of all pesticides were highest for the first runoff event after application and then decreased with each subsequent event. This study indicated that the soil moisture content at the time of a rain event may control the volume of runoff more than the tillage practice. The greater loss of pesticides from no-till may be due to surface crop residue in the no-till plots keeping the pesticides more available for runoff loss than bare soil in the conventional till plots.

Technical Abstract: A two-year study was conducted to evaluate the effect of no-till (NT) and conventional-till (CT) corn production practices on runoff and pesticide loss in runoff from natural rainfall. Runoff from duplicate NT and CT plots (0.25 to 0.5 ha) was measured and the water analyzed for atrazine, cyanazine and alachlor. Runoff of water was greater from NT than from CT plots when the time between rainfall events was less than 7 days, but runoff from CT was greater than NT when 7 or more days passed between rains. Atrazine and cyanazine concentrations were 2 to 10 times higher in runoff from NT than from CT; alachlor concentrations were unaffected by tillage. Concentrations of all pesticides were highest for the first runoff event after application and then decreased rapidly with each subsequent runoff. The time between application and the first runoff event was 3 and 8 days for 1990 and 1991, respectively, which resulted in 5 to 10 times higher concentrations of all pesticides in the first event for 1990 than 1991. Total loss (percent of applied) of atrazine, cyanazine and alachlor was 1.5, 1.6, and 0.3 (NT) and 1.0, 0.7, and 0.5 (CT), respectively, for 1990; corresponding losses for 1991 were 0.8, 0.6 and 0.2 (NT) and 0.3, 0.2 and 0.2 (CT).

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PURIFICATION AND CHARACTERIZATION OF AN S-TRIAZINE RING CLEAVAGE ENZYME FROM E. COLI CARRYING THE TRZD GENE FROM PSEUDOMONAS SP. NRRLB-12227

KARNS, J S

Interpretive Summary: Herbicides based on the s-triazine ring structure are commonly used in agriculture around the world. Over 80 million pounds were used in the US in 1991. Little is known about the biochemistry of s-triazine degradation. In this study the gene encoding the enzyme that opens the s-triazine ring so that the carbon and nitrogen contained in it can be mineralized was cloned from its natural bacterial host into the bacterium E. coli so that it could be produced in large quantity. This enzyme was completely purified and several important kinetic parameters were determined. The enzyme was shown to be very specific for the compound cyanuric acid and would not open the ring of any other s-triazine or related pyrimidine compounds. The pyrimidine compound barbituric acid was found to be a potent inhibitor of s-triazine ring cleavage by this enzyme. The enzyme has been named cyanuric acid amidohydrolase

Technical Abstract: Pesticides based on the s-triazine ring structure are widely used in the cultivation of food crops. Cleavage of the s-triazine ring is an important step in the mineralization of s-triazine compounds and hence in their complete removal from the environment. Cyanuric acid amidohydrolase cleaves cyanuric acid (2,4,6-trihydroxy-s-triazine) to yield carbon dioxide and biuret, which is subject to further metabolism yielding carbon dioxide and ammonia. The trzD gene encoding cyanuric acid amidohydrolase was cloned from Pseudomonas sp. NRRLB-12227, a strain that is capable of utilizing s-triazines as nitrogen sources. The trzD gene was cloned into pMMB277 and transformed into E. coli DH5 where expression of trzD was directed by the lac promoter. The hydrolysis of cyanuric acid was detected in crude extracts by monitoring the disappearance of cyanuric acid and the appearance of biuret by HPLC. DEAE and hydrophobic interaction HPLC were used to purify cyanuric acid amidohydrolase to homogeneity and a spectrophotometric assay was developed for the assay of the purified enzyme. The purified enzyme had an apparent Km of 0.05 mM for cyanuric acid at pH 8.0. The enzyme failed to cleave any other s-triazine or hydroxypyrimidine compounds although barbituric acid was found to be a strong competitive inhibitor

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BIOMINERALIZATION OF ATRAZINE OZONATION PRODUCTS. APPLICATION TO THE DEVELOPMENT OF A PESTICIDE WASTE DISPOSAL SYSTEM.

LEESON, A; HAPEMAN, C J; SHELTON, D R

Interpretive Summary: Interpretive Summary: Concern for pesticide contaminated soils, wells, ground and surface waters has demanded development of remediation strategies. Research has demonstrated that oxidation transforms pesticides into materials that can be more easily mineralized (degraded to carbon dioxide, ammonia, inorganic salts, etc.) by microorganisms. The oxidized compounds are often used by the organisms as carbon sources and energy for growth, but this is not true for atrazine, the one of the most widely used herbicides in the U.S. Oxidation of atrazine using ozone gives rise to chlorodiamino-s-triazine (CAAT), which can be used only as a nitrogen source. Unfortunately, many pesticide waste mixtures also contain ammonia which is the preferred nitrogen source for most microorganisms. A bacterium (DRS-1) was isolated from sewage sludge that used CAAT as a nitrogen source, even in the presence of high ammonia concentrations. The rate of CAAT mineralization in the presence of different ammonia concentrations was determined. Kinetic constants for CAAT degradation by DRS-1, which are needed to optimize bioreactors in treatment systems, were estimated. Two bench scale bioreactors were fabricated and DRS-1 readily degraded CAAT under simulated field conditions. This study demonstrated that together, oxidation and microbial mineralization could readily convert atrazine to carbon dioxide and useful nitrogen compounds.

Technical Abstract: Development of remediation techniques for unusable pesticide wastes has led to a binary scheme involving ozonation followed by biomineralization of the resultant oxidized pesticides. Preliminary field tests of this technique indicated that the s-triazines were somewhat more recalcitrant than the other pesticides present. Further experiments identified the final ozonation products of atrazine, the most widely used s-triazine, as 4-acetamido-6-amino-2-chloro-s-triazine (CDAT) and chlorodiamino-s-triazine (CAAT). These compounds can be utilized by microorganisms only as nitrogen sources, however, 1% concentrations of ammonia fertilizers are not uncommon in pesticide waste. Therefore, the organism should prefer an organic nitrogen source and tolerate high ammonia concentrations. A gram positive rod, DRS-I, was observed to degrade CAAT in the presence of high ammonia concentrations (0.8 M) with the addition of a carbon source (corn syrup), in contrast to a known s-triazine degrading organism which could not. Near complete mineralization of CAAT to CO2 by DRS-I was demonstrated using CAAT-U-ring-14C. Bench scale reactors indicated that continuous flow or fixed-film reactors would support growth of DRS-I cultures and CAAT degradation.

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MOBILITY OF AGROCHEMICALS UNDER TWO TILLAGE SYSTEMS

LEVANON, D; CODLING, E E; MEISINGER, J J; STARR, J L

Interpretive Summary: During the last decade there has been a major shift by farmers from plow tillage (PT) towards conservation tillage and no-tillage (NT). Concern has been raised regarding the possibly greater leaching of chemicals to the ground water under conservation tillage. This laboratory study was conducted to determine the influence of recent PT versus long-term NT on the movement of bromide, nitrate, and four pesticides through surface soil under severe leaching conditions. Strong evidence was found for preferential flow through the soil, with the chemicals by-passing much of the soil-matrix under recently plowed soils and NT soils. Nitrate leaching was significantly greater under PT than NT, apparently due to the greater mineralizing activity of the PT. The higher organic matter content of the upper portion of the NT soil probably caused more adsorption of the pesticides. Caution should be exercised in generalizing from laboratory to field conditions, but his data suggests that there can be greater leaching losses of surface applied agrochemicals to groundwater under PT than under NT. This laboratory study provided additional insight on the influence of tillage on leaching of fertilizers and pesticides applied to agricultural soils, and should be most useful to scientists in planning further research.

Technical Abstract: The fate of agrochemicals is often greatly affected by the surface-soil conditions in the field. This study was conducted to characterize the impact of two contrasting tillage systems on the movement of agrochemicals in soil. The two tillage systems were plow-(PT) and no-tillage (NT) for corn (Zea mays, L.) production. The study included incubation and leaching of undisturbed soil columns and disturbed soil samples from 17-yr mono-tillage plots. The agrochemicals used in the study were NH4NO3, atrazine (2-chloro-4-ethylamino-6-isopropylamino- 1,3,5-triazine-2,4 diamine), carbofuran (2,3-dihydro-2,2- dimethyl-7-benzofuranyl methylcarbamate), diazinon (0,0- diethyl-0-(6-methyl-2(1-methylethyl)- 4-pryamidinyl phosphor-othioate), and metolachlor (2-chloro-N-(2-ethyl -6-methylphenyl) -N-(2-metoxy-1-methylethyl) acetamide. The results of this study show greater ponded flow movement of all agrochemicals in soils under PT vs. NT conditions. Strong evidence was found for preferential flow through the soil, with the chemicals by-passing much of the soil-matrix under recently plowed soils as well as NT soils. Nitrate leaching was significantly greater under PT than NT, apparently due to greater mineralizing activity of the PT soil compared to the NT soil. The pesticide movement also tended to be greater under PT than NT. Caution should be exercised in generalizing to field conditions, but this data suggests that there can be greater leaching losses of surface applied agrochemicals to groundwater under PT than under NT.

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IMPACT OF TILLAGE ON MICROBIAL ACTIVITY AND FATE OF PESTICIDES IN THE SOIL

LEVANON, D; MEISINGER, J J; CODLING, E E; STARR, J L

Interpretive Summary: The use of conservation tillage, and in particular no-tillage, has expanded greatly in the past decade. However, the impacts of conservation tillage on mobility of pesticides is still largely unknown. A laboratory incubation study was undertaken to evaluate the impacts of no-tillage vs. plow-tillage on pesticide degradation and subsequent mobility, using disturbed surface soil samples collected from long-term tillage plots from the Piedmont region of Maryland. The pesticides studied were isotope labelled atrazine, carbofuran, diazinon, and metolachlor. We found greater mobility of these pesticides in plow-tillage soil than in no- tillage soil. The lower mobility of pesticides in no-tillage was attributed to greater numbers of microbes and a greater activity of microbes which increased pesticide biodegradation. This is consistent with greater supply of residues and higher organic matter levels with no- tillage. This research is of interest to scientists and modelers who are interested in the transformation of pesticides as affected by modern tillage systems.

Technical Abstract: A study was made of the impact of two tillage systems, plow-tillage (PT) and no-tillage (NT), on microbial activity and the fate of pesticides in surface soil. The pesticides were atrazine, carbofuran, diazinon, and metolachlor. The study involved incubation of the pesticides in disturbed soil and the leaching of the pesticides from the soil after various periods of time. The soils were also treated with selective inhibitors of fungi or bacteria, with a total microbial-biocide, or were untreated to study the interaction between microbial communities in pesticide degradation. The biodegradation of ring C-14 labeled pesticides was also studied. Pesticide mobility was greater in PT soil than NT soil. Higher microbial populations and greater microbial activity in NT soil caused higher mineralization rates of atrazine, diazinon and carbofuran. Enhanced rates of biotransformation played an important role in reducing the mobility of metolachlor and carbofuran in NT soils. Synergistic effects between fungi and bacteria were observed in the degradation of atrazine and diazinon. Carbofuran, however, was also degraded in the soils where fungi were selectively inhibited. Possible mechanisms for enhanced biodegradation and decreased mobility of these pesticides in NT soil are discussed.

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LONG-RANGE ATMOSPHERIC TRANSPORT OF TOXAPHENE TO LAKE BAIKAL

MCCONNELL, L L; KUCKLICK, J B; BIDLEMAN, T F; WALLA, M D

Interpretive Summary: Lake Baikal holds 20% of the world's freshwater supply and supports hundreds of indigenous plants and animals. Increased anthropogenic activity has threatened this fragile ecosystem. Studies have shown that atmospheric deposition can be an important pathway for agricultural chemicals such as pesticides to enter large lakes. This manuscript focuses on inputs of one pesticide, toxaphene. Using results from air and water samples collected there in June, 1991, the authors predict that significant amounts of this pesticide are entering the lake through atmospheric deposition processes.

Technical Abstract: Complex mixtures of chlorinated bornanes and borenes (CHBs), typically referred to as toxaphene or polychlorinated camphenes, were measured in the air and surface water of Lake Baikal, Russia during June, 1991. The mean CHB concentration was 16 plus or minus 4 pg m-3 in air and 64 plus or minus 37 pg/L in water. Levels in air were similar to previous measurements in Arctic regions, and the chromatographic pattern of CHB congeners was extremely "weathered" compared to a toxaphene standard, suggesting long-range atmospheric transport rather than a nearby source. The congener pattern in the water samples was similar to that in the air, indicating the importance of atmospheric deposition processes to Lake Baikal. Estimates of gas flux of CHBs across the air-water interface predict that this process could cause a substantial contribution to the lakes' overall pollutant budget

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DEVELOPMENT OF ALGORITHMS FOR DETECTING NITROGEN FERTILIZATION LEVELS IN FIELD CORN (ZEA MAY L.) WITH LASER INDUCED FLUORESCENCE

MCMURTREY, J E III; CHAPPELLE, E W; KIM, M S; MEISINGER, J J; CORP, L A

Interpretive Summary: Immediate and specific indications of changes in condition of crop physiology and crop metabolism are not being met by the current mo of non-destructive testing or remote sensing of crop canopies. An active sensing technique, Laser Induced Fluorescence (LIF), was investigated for its' potential use in detecting differences in co plants caused by level of nitrogen fertilization. Treatments in t test ranged from over fertilization to extreme deficiency. Reflectance techniques were compared to LIF measurements and were tested for their ability to determine the concentration of the pri plant pigments. LIF tend to be able to distinguish between higher levels of nitrogen fertilization in corn. Whereas reflectance techniques tended to be able to separate lower levels of nitrogen fertilization in corn. Successful development of LIF combined wit reflectance techniques can lead to non-destructive and perhaps rem methods of sensing immediate and specific changes in the condition crop canopies. More cost efficiency in fertilizer use and control water pollution by N fertilizer.

Technical Abstract: Laser induced fluorescence (LIF) is an active sensing technique capable of capturing immediate and specific indications of changes plant physiology and metabolism as they relate to the concentration and photosynthetic activity of the plants pigments. Reflectance i passive sensing technique which can capture differences in the concentration of the primary plant pigments. Fluorescence and reflectance were compared for their ability to measure levels of p stress that are of agronomic importance in a field corn crop. Laboratory LIF and reflectance spectra were made on excised leaves from field grown corn (Zea _mays L.). Changes in the visible region of the spectrum were compared between groups of plants fertilized seven different levels of nitrogen (N) fertilization. A pulsed nitrogen laser emitting photons at a wavelength of 337 nm was used a fluorescence excitation source. Differences in maximum intensity fluorescence occurred at 440, 525, 685, and 740 nm. Significant separations were found between levels of N fertilization at several LIF wavelength ratios. Several reflectance algorithms also produce significant separations between certain levels of N fertilization.

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CORN UTILIZATION OF LABELLED NITROGEN FERTILIZER UNDER MINIMAL AND MOLDBOARD TILLAGE

MEISINGER, J M; BANDEL, V A

Interpretive Summary: Conservation tillage systems are being widely accepted by corn producers due to their excellent control of soil erosion and their reduced labor requirements. This study compared soil and fertilizer nitrogen uptake by corn grown under no-tillage or plow-tillage culture over a four-year period in the Piedmont region of Maryland. Nitrogen fertilizer was applied to each tillage system at five rates ranging from 0 to 160 lbs N/acre annually. The fertilizer was labelled with a nitrogen isotope which allowed researchers to trace the fertilizer into the corn crop. By sampling the corn at various growth stages the researchers learned that tillage treatments did not greatly affect silage yields, total nitrogen uptake, or fertilizer nitrogen uptake. The silage corn recovered an average of 44% of the fertilizer nitrogen on no-tillage plots and 47% on plow-tillage plots. Corn grown with no tillage required about 27 lbs more fertilizer nitrogen per acre than plow-tillage corn because soil nitrogen uptake was somewhat lower in the no-tillage corn. These results will help researchers and extension agents understand the dynamics of nitrogen utilization by corn as affected by tillage practices. This information will aid in devising more efficient nitrogen management strategies for conservation tillage systems, and will help reduce losses of nitrogen to the environment.

Technical Abstract: A 4-yr field experiment was conducted in the Piedmont region of Maryland on Delanco silt loam (fine-loamy, mixed, mesic, Aquic Hapludult) which compared fertilizer N (FN) utilization by corn (Zea Mays L.) grown under moldboard plow (PT) or minimal tillage (MT) culture at five FN rates ranging from 0 to 180 kg FN ha-1 yr-1. Labeled ammonium sulfate or ammonium nitrate (15N depleted) was surface applied at planting to 74 m2 plots and corn dry matter yield, N content, and isotope composition were determined in the aboveground plant at the 11 to 12 leaf stage, at silage harvest, and in the corn grain at maturity. Tillage treatments produced no consistent or practically significant effects on soil N (SN) uptake. Silage FN uptake efficiencies were not significantly affected by tillage or FN rate; MT recoveries averaged 44% compared to 47% for PT. Average SN uptakes were somewhat greater for PT than for MT, averaging 105 and 97 kg SN ha-1, respectively. The MT corn required about 30 kg more FN ha-1 to achieve N sufficiency than PT, due to the lower utilization of SN with MT culture. Minimal tillage corn accumulated less SN than PT corn during the first half of the growing season, but no differences in SN vs. FN uptake were observed during the last half of the growing season. A N concentration of 11 to 12 g N kg-1 in the silage total dry matter, or 14 to 15 g N kg-1 in the grain, can be used as approximate values of N sufficiency, but significant deviations from these levels occurred in several years.

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PREDICTING N FERTILIZER NEEDS FOR CORN IN HUMID REGIONS: UNDERLYING PRINCIPLES

MEISINGER, J J; MAGDOFF, F R; SCHEPERS, J S,

Interpretive Summary: Society is concerned about nitrate enrichment of groundwater. The agriculture community shares this concern and has made major improvements over the past 10 years in predicting fertilizer N needs for corn in humid regions.These improvements have involved: clarification of procedures to estimate expected yields, expanded use of the preplant soil nitrate test into humid areas, development and implementation of the pre-sidedress soil nitrate test, and the environmental evaluation and improvement of previous N recommendation systems. Adoption of the pre-sidedress soil nitrate test has been the most significant advance in humid region soil N testing in the past decade. This test is based on the timely monitoring of the field mineralization process and is well suited to warm-season crops and silt loam soils. This test can identify N sufficient sites i.e., sites needing little or no extra fertilizer N. The test will help extension agents, soil conservationists, and farmers identify N sufficient sites and thereby: conserve fertilizer N, improve N use efficiency, and reduce nitrate losses to groundwater.

Technical Abstract: Nitrogen is a mobile and dynamic nutrient, especially in humid climates. Predicting N fertilizer needs for corn in humid regions is based on N balance principles which result in N predictions being based on crop factors, soil N supply, and climatic factors. The crop factors are usually addressed through some type of predicted yield estimate, which offers the advantage of integrating many local production factors. However, this approach can also be greatly misused if careful attention is not given to definition of terms and the method used to actually estimate the expected yield. The soil N supply factors are usually assessed through a preplant soil NO3-N measurement, a general estimate of N mineralization through soil organic matter content, a N credit adjustment (e.g., legume or manure credit), or the use of the pre-sidedress soil nitrate test(PSNT). The NO3-N content of humid temperate soils growing corn exhibits rhythmic patterns of: low levels after winter leaching/denitrification, an accumulation of NO3-N in spring and early summer due to the resumption of mineralization, a dramatic decline in summer due to corn N uptake, and a modest increase in fall due to continued mineralization and no crop uptake. The underlying principles of the PSNT reveal that it is an in situ N mineralization test that is well suited for warm-season crops and fine-textured soils. Future improvements will likely include: i) expanded use of the PSNT, ii) inclusion of more site specific information, site weather or soil taxonomic data, and iii) expanded use of N management models to interpret soil N tests and integrate the complex factors affecting soil N transformations into a more fully unified system.

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IN VIVO IMAGING OF THERMODYNAMIC PROPERTIES OF WATER RELAXATION IN THE GYPSY MOTH (LYMANTRIA DISPAR (L.))

MILLARD, M; LINE, M; GASSNER, G; SCHMIDT, W; CALDWELL, C

Interpretive Summary: Contrast or picture intensity from dark to bright in Magnetic Resonance Imaging (MRI) is presently determined by the rate of loss of magnetic energy by mobile water molecules while relaxing in living tissue. Water mobility and therefore contrast in living tissue is related to cell physiology and therefore is affected by disease states and temperature changes. A new theory is presented based on obtaining the temperature dependence of water relaxation in living tissue that yields images whose contrast is based on the energy required for mobile water molecules to relax in a magnetic field. These new images of living tissue differ greatly from images whose contrast depends on rates or speed of water relaxation rather on the energy required for water relaxation. Measurement of activation energies for water relaxation provides a new basis on which to understand the behavior of water in living tissue and the relationship between water behavior and cell physiology. MRI of living tissue collected at two temperatures allows calculation of the thermodynamic properties for water relaxation in each volume element or pixel in the image. Knowledge of these thermodynamic properties of water relaxation allows calculation and prediction of the behavior of water over wide extremes of temperature between freezing and boiling. This theory provides a model on which to predict the effect of temperature changes on plant physiology.

Technical Abstract: The temperature dependence of the rate of water proton relaxation by the spin dephasing mechanism measured from multi spin echo images can be used to calculate activation energy parameters for water relaxation rates on a pixel by pixel basis. Images whose intensity or contrast is proportional to these activation energy parameters can be constructed by image processing from the proton spin spin relaxation images. Proton spin spin relaxation from individual voxels in images is accurately approximated as a mono-exponential function in the echo time region measured by MRI, indicating a fast exchange mechanism present at the voxel level. The introduction of the temperature parameter makes it possible to visualize and separate the temperature dependent and independent components of the image. The mechanism of water relaxation in heterogeneous tissue is complex. Water relaxation rate activation parameters E, G, H, and S from pixels in tissue can be reference to these same parameters measured for pure water. These new images provide several advantages for imaging water in living tissue. Images based on E and H include negative and positive quantities corresponding to endothermic and exothermic relaxation rate mechanisms. The free energy and entropy of activation images show contrast based upon temperature dependence of proton relaxation rates yielding contrast sensitive to mechanisms not previously detectable in images.

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PESTICIDE MOBILITY IN SOIL. III. DISTRIBUTION OF ETHOPROFOS, CARBOFURAN, ATRAZINE, METRIBUZIN AND CYANAZINE IN SILTY CLAY

MOJASEVIC, M; HELLING, C S; GISH, T J; GOJKOVIE, S

Interpretive Summary: Pesticide leaching into an alluvial soil was influenced strongly by the frequency of water inputs. This paper describes movement and persistence of five pesticides (atrazine, carbofuran, cyanazine, ethoprofos, and metribuzin) in field plots that received frequent irrigation or only natural rainfall. The same total input water, when received within 42 days, moved about 15-20% of recovered pesticides into the 30-70 cm zone (i.e., well below the plow layer); when this water was received in 204 days (a dry summer), only 0-4% of the pesticides moved below 30 cm. Such findings have direct implication to accurate modeling of contaminant transport into and through soil.

Technical Abstract: Persistence and leaching of ethoprofos, carbofuran, atrazine, metribuzin and cyanazine residues in an alluvial soil were studied as a function of water input (tilled, fallow Plots A-frequent irrigation, and C-only natural rain). Samples were collected six times over 42 (A) or 204 (C) days. Pesticide mobility, per compound, was expressed in terms of: (1) mean residue within 5- or 10-cm soil increments (up to 1 m); (2) percent residue per increment relative to the total found per sampling time; and (3) percent residue relative to the initial concentration in soil. Pesticide residues in soil decreased with time and depth. Regardless of the water input regime or sampling time, most (59-99%) atrazine, cyanazine, ethoprofos and metribuzin present at any sampling time remained in the upper 5-10 cm; variability was less than 70%. Carbofuran, the only granular pesticide, was most mobile, but with highly variable mean distribution. Depending on the sampling time, 27-91% of the total residues remained in the surface layer. The frequency of water inputs influenced pesticide leaching. With cumulative water input of 217 mm on Plot A, 20 days after pesticide application, 13-22% of the total recovered pesticides, or 4-10% of the initial deposits, was in the 30-70 cm layer. The second treatment (Plot C) received about the same quantity of water (240 mm) in 49 days. Here only 0-4% of the total pesticide residues, representing up to 1% of initial concentration, was present at 30-70 cm. Estimating pesticide leaching into soil layers beyond 70 cm, which is environmentally important, is made difficult by the great variability of results (300% or more) and very low pesticide concentrations.

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HAPTAN SYNTHESIS AND IMMUNOASSAY DEVELOPMENT FOR THE ANALYSIS OF CHLORODIAMINO-S-TRIAZINE IN TREATED PESTICIDE WASTE AND RINSATE

MULDOON, M T; NELSON, J O; HUANG, R; HAPEMAN, C J; FRIES, G F, MCMICHAEL, C

Interpretive Summary: The triazine herbicides, such as atrazine, are used widely and may be significant components of rinsates, and the soils and groundwater around applicator sites. Simple and reliable analytical methods are required monitoring remediation activities at these sites. Current chromatographic analytical methods for chlorodiamino-s-triazine, an important degradation product of triazine herbicides, are limited by the water solubility and inefficient recovery of this analyte. Several haptens were synthesized and utilized in immunoassay development using both indirect and haptenated enzyme formats. The assays were sensitive in the low micromolar range. Two assays were optimized and validated by comparison with a high pressure liquid chromatography method for the analysis of chlorodiamino-s-triazine in treated pesticide waste samples. It is anticipated that this immunoassay will provide a useful monitoring technique for on-site sampling and remediation of pesticide contaminated areas.

Technical Abstract: A significant environmental degradation product of chloro-s-triazine herbicides is chlorodiamino-s-triazine. Current chromatographic analytical methods are limited by the water solubility and inefficient recovery of this analyte. A diamino-s-triazine hapten was synthesized for the production of polyclonal antibodies. Other haptens were synthesized which differed in bridging group and ring substitution for use in immunoassay development using both indirect and haptenated-enzyme formats. In general, antibody recognition of substituted s-triazines decreased as a function of amino side chain substitution. The assays were sensitive in the low micromolar range. Two assays were optimized and validated by comparison with a HPLC method for the analysis of chlorodiamino-s-triazine in treated pesticide waste samples. The correlation coefficients found were 0.988 and 0.979. It is anticipated that this immunoassay will provide a useful monitoring technique for on-site sampling and remediation of pesticide contaminated areas.

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PURIFICATION AND CHARACTERIZATION OF AN INDUCIBLE S-TRIAZINE HYDROLASE FROM RHODOCOCCUS CORALLINUS

MULBRY, W W

Interpretive Summary: The widespread use and relative persistence of s-triazine compounds such as atrazine have lead to increasing concern about environmental contamination by these compounds. Alkylated s-triazine compounds such as atrazine are relatively recalcitrant to biodegradation processes in soil. It is therefore not surprising that few microorganisms have been identified that degrade these compounds at rates that would be useful for environmental remediation. In this study, scientists characterized a unique bacterial enzyme that is capable of removing chlorines or ammonia groups from certain s-triazines. This information will help in our understanding of how such enzymes work and how there levels are controlled by the cell. In addition, such knowledge will aid in the isolation of other s-triazine degrading organisms and will lead to the development of better remediation technologies.

Technical Abstract: The widespread use and relative persistence of s-triazine compounds such as atrazine and simazine have lead to increasing concern about environmental contamination by these compounds. Few microbial isolates have been identified that are capable of transforming substituted s-triazines. Rhodococcus corallinus NRRL B-15444 has previously been shown to possess a hydrolase activity that is responsible for the dechlorination of the triazine compounds deethylsimazine (6-chloro-N-ethyl-1,3,5-triazine-2,4-diamine) (CEAT) and deethylatrazine (6-chloro-N-isopropyl-1,3,5-train-2,4-diamine) (CIAT). The enzyme responsible for this activity was purified and was shown to be composed of four identical subunits of 50,000 daltons. Kinetic experiments revealed that the purified enzyme is also capable of deaminating the structurally related s-triazine compounds melamine (2,4,6-triamino-1,3,5-triazine) (AAAT) and CAAT (2-chloro-4,6-diamino-1,3,5-triazine) as well as the pyrimidine compounds 2,4,6-triaminopyrimidine (AAAP) and 4-chloro-2,6-diaminopyrimidine (CAAP). The triazine herbicides atrazine and simazine inhibit the hydrolytic activities of the enzyme but are not substrates. Induction experiments demonstrate that triazine hydrolytic activity is inducible and that this activity rises approximately twenty-fold during induction.

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THE ORGANOPHOSPHATE ACID ANHYDRASE GENE OPAB FROM THE GRAM-POSITIVE STRAIN B-1: CLONING, NUCLEOTIDE SEQUENCE, AND EXPRESSION IN E. COLI.

MULBRY, W W

Interpretive Summary: Parathion hydrolases are bacterial enzymes that carry out the first step of the degradation of many organophosphate pesticides. In this study a new parathion hydrolase gene was isolated and its DNA sequence was determined. Although the protein specified by this new gene has roughly similar substrate affinities to a previously characterized Flavobacterium parathion hydrolase, its enzymatic activity is much lower than the Flavobacterium enzyme. By carefully comparing the genes for these two enzymes scientists can begin to unravel the basis of their catalytic differences and may be able to design better enzymes for pesticide waste disposal.

Technical Abstract: The organophosphate acid (OPA) anhydrases (previously termed parathion hydrolases) from the Gram-positive bacterial strain B-1 and Flavobacterium sp. ATCC 27551 display roughly similar affinities for the substrate ethyl parathion as well as similar pH and temperature optima. However the two enzymes are quite distinct with respect to their sizes, cellular locations, relative affinities for ethyl parathion and the structurally related organophosphate insecticide O-ethyl-O-4-nitrophenyl phenylphosphonothioate (EPN), and stimulation or inhibition by divalent cations and DTT. The first twenty amino-terminal residues of the purified strain B-1 OPA anhydrase were determined. Two degenerate oligonucleotide were synthesized and used in a DNA amplification reaction to generate a 73 base pair DNA fragment from the B-1 gene opaB. The nucleotide sequence of the 73 base pair fragment was determined and a nondegenerate oligonucleotide probe for the opaB gene was designed from this sequence. A 3.55 kilobase DNA fragment which hybridized to the opaB probe was cloned and the nucleotide sequence of a 1600 base pair region containing opaB was determined. Under control of the lac promoter of pUC19, opaB expression in E. coli cultures was approximately 15-fold higher than in strain B-1 under the opaB native promoter. Comparison of opaB and opd revealed no significant regions of homology at the nucleotide or amino acid sequence level.

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INTERPOLATION OF SOIL HYDRAULIC PROPERTIES BY PIECEWISE POLYNOMIALS

PACHEPSKY, Y; TIMLIN, D

Interpretive Summary: Continuous and smooth relationships between hydraulic conductivity and matrix potential, and between moisture content and matrix potential are commonly constructed from a limited number of data points by some method of interpolation or approximation that unavoidably smoothes the data. This may result in a significant loss of information. This in turn can have an impact on the results of water quality simulation models that use these smoothed data in calculations of water movement in soils. In this paper we present an improved method to interpolate water contents from soil matrix potentials that preserves the shape of the original data. In simulations of ponded infiltration, calculated results, using the improved method to represent the moisture release curves, were closer to measured data during early stages of infiltration than were results from simulations using another commonly used method of representing moisture release data.

Technical Abstract: Continuous and smooth relationships between hydraulic conductivity and matrix potential, and between moisture content and matrix potential are commonly constructed from a limited number of data points by some method of interpolation or approximation that unavoidably smoothes the data. This may result in a significant loss of information. This in turn can have an impact on the results of water quality simulation models that use these smoothed data in calculations of water movement in soils. We present an improved method, utilizing a piece-wise polynomial, to interpolate water contents from soil matrix potentials at midpoints between pairs of measured data. This method preserves the shape of the moisture release curve. The results of simulations of ponded infiltration using the improved method to represent the moisture release curve are compared to results using a logistic equation to represent the moisture release curve. Predicted matrix potentials, using values from the piecewise polynomial, were closer to measured data during early stages of infiltration. The predicted infiltration rate, using values from the logistic function was much less than the measured infiltration rate or the rate predicted using the piecewise polynomial. This suggests that high infiltration rates usually attributed to macropores may be simulated using a more realistic description of the moisture release curve near saturation.

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TEMPERATURE AND MOISTURE EFFECTS ON CARBOFURAN DEGRADATION IN SOIL

PARKIN, T B; SHELTON, D R

Interpretive Summary: Prediction of the fate of pesticides in soil is of interest from an environmental (pollution) as well as an agricultural (efficacy, carryover) viewpoint. In addition to accounting for transport mechanisms, accurate prediction of the fate of pesticides in soil must also account for degradation due to microbial activity. Two environmental parameters which control microbial degradation of pesticides in soil are moisture and temperature. This study was designed to quantify the impact of soil moisture and temperature on the microbial degradation of the insecticide carbofuran. Soils were incubated at 7 soil water tensions over the range of 0.03 to 1.5 MPa, and at four different temperatures (10 degrees C to 30 degrees C). It was observed that degradation activity increased with increasing soil moisture. A mathematical relationship was derived which summarizes the response of carbofuran degradation activity. The response of carbofuran degradation to temperature was also well described by an exponential relationship, from which it was estimated that each 10 degrees C increase in temperature carbofuran degradation activity increased by a factor of 1.68. This study provides quantitative mathematical relationships required for development of predictive models of pesticide fate in soil.

Technical Abstract: This study was designed to quantify the impact of soil water content and temperature on microbial degradation rates of the insecticide carbofuran. Carbofuran degradation was determined by monitoring the 14CO2 production from carbonyl-labeled carbofuran amended soils. Soils were incubated at 7 soil water tensions over the range of 0.03 to 1.5 MPa, and at four different temperatures (10 degrees C to 30 degrees C). The sigmoidal degradation kinetics observed from these incubations were modeled using a general saturation model. From this analysis two summary parameters were computed; the maximum rate of carbofuran degradation and the time required for disappearance of 50% of the added carbofuran (DT-50%). For the moisture experiments both maximum rate of hydrolysis and DT-50% were accurately modeled by an exponential relationship (r2 of 0.9930 and 0.9720, respectively). The response of carbofuran degradation to temperature was also well described by an exponential relationship, from which it was estimated that the Q10 associated with the maximum rate was 1.68, and the Q10 for DT-50% was 1.89.

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SPATIAL VARIABILITY OF MICROBIAL PROCESSES IN SOIL

PARKIN, T B; SHELTON, D R

Interpretive Summary: Microbial transformations of fertilizers and pesticides in the surface soil have a direct impact on the mass of the agrochemical which is susceptible to leaching losses. Thus, our greatest potential for controlling leaching losses of agrochemicals is through the management of these compounds in the surface soil. A variety of strategies have been employed to maximize the residence time of applied chemical in the surface soil, including: timing of application, formulation (e.g. slow release fertilizers and encapsulated pesticides), and the use of compounds which modify microbial activity in soil (e.g. nitrification inhibitors). While these strategies have met with some success, more precise quantification of the microbial transformations of agrochemicals is required to aid the development of improved management strategies. The high temporal and spatial variability exhibited by many microbial processes, in many cases, precludes precise quantification. This paper provides a general review of past work on the spatial variability associated with microbial processes in soil. This discussion focuses on the scale at which variability is expressed as well as the soil/environmental factors which impact variability. Basic strategies for dealing with variability are presented.

Technical Abstract: Prediction of the fate of agrochemicals in the environment requires knowledge of the factors which control microbial degradation rates. This necessarily requires determination of the spatial and temporal variability associated with pesticide degradation rates and fertilizer transformations in soil. This paper presents a summary of recent concepts in quantifying the spatial and temporal variability associated with microbial processes in soil, and reports on statistical procedures for the analysis and interpretation of data. The concepts developed in the general discussion of variability are illustrated by a presentation of a specific study of the factors contributing to the spatial and temporal variability associated with the microbial degradation of the insecticide carbofuran.

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EXIT CONDITION FOR MISCIBLE DISPLACEMENT EXPERIMENTS

PARLANGE, J; STARR, J L; VAN GENUCHTEN, M T; BARRY, D A; PARKER, J. C.

Interpretive Summary: Concern about soil and groundwater pollution has motivated the development and testing of mathematical models to predict how agricultural chemicals move through the unsaturated zone between the soil surface and the groundwater table. Computer models for field conditions are often tested in the laboratory under controlled conditions using relatively short (finite) soil columns.Results of such studies provide useful data for extrapolation to field-scale conditions, provided the particular features of a soil column are accounted for, notably the finite length of the column as opposed to the semi-infinite setting of a field soil profile. This paper presents several equations which may be used to minimize potential errors caused by the fact that laboratory soil columns have a finite length. Results are important for modelers and experimentalists using laboratory soil column experiments in efforts to mimic field-scale chemical transport processes.

Technical Abstract: The one-dimensional solute transport is analyzed with the convection-dispersion model, including first and zeroth order irreversible reaction. A simple analytical expression is derived for the residence concentration which depends explicitly on the exit conditions at the end of the soil column or layer. The validity of the flux concentration solution ignoring the finite length of the column is also discussed by relating the exit conditions to the Peclet number

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QUANTITATIVE ASSESSMENT OF GROUNDWATER QUALITY USING A BIOLOGICAL INDICATOR: SOME PRELIMINARY OBSERVATIONS

PFEIL, R M; NAIR, P P; VENKAT, J A; PLIMMER, J R; SHAMI, S; DAVIS, K

Interpretive Summary: A major concern today is the impact of agricultural practices on groundwater quality. Groundwater samples from different agricultural areas were evaluated for mutagenicity using a standard bacterial test, the SOS microplate assay (SOSMA). Organic compounds were concentrated from groundwater samples from Maryland, Pennsylvania, and Delaware. The mutagenicity of the concentrated compounds was determined by the SOSMA. Relative activity (RA) as determined by the SOSMA is a quantitative measure of mutagenicity based on a comparison to the activity of the mutagen, 4-nitroquinoline oxide. Low levels of activity (about 2x background) were detected in waters from sites within these states. Additionally, total organic carbon content (TOC) of water samples was also determined. Between sampling sites there was a positive correlation between RA and TOC; however, this relationship appeared to be reversed occasionally within a sampling site. Groundwater sampled from several different agricultural practices and sites possessed low levels of activity.

Technical Abstract: The mutagenicity of groundwater was evaluated using a novel application of the SOS microplate assay (SOSMA). Organic residues were extracted from groundwater samples from Maryland, Pennsylvania, and Delaware by using C- 18 bonded silica solid phase extraction tubes. Total organic carbon content (TOC) of water samples was also determined. The mutagenicity of dried extracts was determined by the SOSMA. Relative activity (RA) as determined by the SOSMA is a quantitative measure of mutagenicity based on a comparison to the activity of the mutagen, 4-nitroquinoline oxide. Low levels of RA (about 2x background) were detected in waters from sites within these states. There was considerable temporal and spatial variation in the observed RA but no definite patterns were observed in the variation. Between sampling sites there was a positive correlation between RA and TOC; however, this relationship appeared to be reversed occasionally within a sampling site. The extraction and bioassay methods provide an easy and relatively inexpensive means of determining water quality.

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TEMPORAL VARIABILITY OF INFILTRATION FOR AGRICULTURAL SYSTEMS

RAWLS, W J; ONSTAD, C A; BRAKENSIEK, D L

Interpretive Summary: Rainfall simulation experiments were conducted on a Barnes loam and Bearden silty clay loam at planting, midseason and harvest to determine the effect of rainfall intensity, prior crops, bare ground, crop canopy, residue and a combination of crop canopy and residue on the temporal steady state infiltration rate. The results illustrate that agricultural systems cause significant temporal effects on infiltration which needs to be incorporated into infiltration models in order to evaluate the effect of agricultural systems on runoff, erosion and water quality.

Technical Abstract: Rainfall simulation experiments were conducted on a Barnes loam and Bearden silty clay loam at planting, midseason and harvest to determine the effect of rainfall intensity, prior crops, bare ground, crop canopy, residue and a combination of crop canopy and residue on the temporal steady state infiltration rate. The steady state infiltration rate of bare ground decreased and then stabilized over the season. Canopy and residue maintained a higher steady state infiltration rate than that of bare ground, however, they did not produce an accumulative effect. Increases in rainfall intensity increased the steady state infiltration rate of bare ground. Plowing under sod increased the steady state infiltration rate; however, this effect was not maintained over the season.

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A MODIFIED MARSHALL EQUATION FOR PREDICTING MATRIX AND MACROPORE SATURATED HYDRAULIC CONDUCTIVITY

RAWLS, W J; BRAKENSIEK, D L; LOGSDON, S D

Interpretive Summary: The prediction of the movement of water through the soil is needed to quantify the effects of agricultural practices on water quality. A prediction model based on pore size distribution was developed that predicted the hydraulic conductivity of the soil and macropores independently. This model allows us to evaluate specifically the effect of agricultural practices on the pore distribution and thus developed agricultural systems accordingly.

Technical Abstract: Equations for predicting matrix and macropore saturated hydraulic conductivity were developed by coupling the Sierpinski carpet algorithm with the Marshall saturated hydraulic conductivity formulation. The parameters matrix and macropore porosity, maximum pore radius, and the number of pore classes ere related to soil properties to enable the equations to be used for a wide range of soils.

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USING FRACTAL PROCESS TO PREDICT MATRIX AND MACROPORE SATURATED HYDRAULIC CONDUCTIVITY WITH THE MARSHALL EQUATION

RAWLS, W J; BRAKENSIEK, D L; LOGSDON, S D

Interpretive Summary: The prediction of the movement of water through the soil is needed to quantify the effects of agricultural practices on water quality. A prediction model based on pore size distribution was developed that predicted the hydraulic conductivity of the soil and macropores independently. This model allows us to evaluate specifically the effect of agricultural practices on the pore distribution and thus developed agricultural systems accordingly.
Technical Abstract: Preferential movement of surface applied chemicals to the groundwater has resulted in a great need to physically model the movement of water into and through the soil media. The objective of this study is to develop equations capable of predicting both matrix and macropore saturated hydraulic conductivity and relate the equation parameters to readily available soil properties. Equations for predicting the matrix and macropore saturated hydraulic conductivity were developed coupling fractal processes with the Marshall saturated hydraulic conductivity formulation. The equation uses matrix and macropore porosity, maximum pore radius, and number of pore classes. Prediction equations were developed relating the number of pore classes and maximum pore radius to soil properties. The modified Marshall saturated hydraulic conductivity equation appears to provide reasonable estimates of matrix and macropore saturated hydraulic conductivity and is applicable to a wide range of soil textures.

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SEASONAL EFFECTS OF AGRICULTURAL PRACTICES ON INFILTRATION

RAWLS, W J; ONSTAD, C L; BRAKENSIEK, D L

Interpretive Summary: For accurate prediction of runoff the temporal effects of agricultural practices on infiltration need to be described. A set of field experiments were conducted to determine the effects of agricultural practices on infiltration. The experiments demonstrated the combined effect of canopy cover, ground cover and bare ground on infiltration and illustrated the need to incorporate these effects into infiltration models.

Technical Abstract: Rainfall simulation experiments were conducted on a Barnes loam at planting, midseason and harvest to determine the effect of bare soil surface, crop canopy, crop residue, ground cover and a combination of crop canopy and residue ground cover on the steady state infiltration rate. The steady state infiltration rate of bare soil surface decreased and stabilized over the season. Canopy and residue maintained a higher steady state infiltration rate than that of bare soil surface. Increases in canopy increased the steady state infiltration rate.

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CARBON DIOXIDE ENRICHMENT AND TEMPERATURE EFFECTS ON ROOT GROWTH IN COTTON

REDDY, V R; REDDY, K R; ACOCK, M C; TRENT, A

Interpretive Summary: CO2-enrichment can enhance crop growth and yield under ideal conditions, but if CO2-enrichment is accompanied by global warming, there may be additional evaporative demands made on the crop. The ability of the crop to meet these demands will depend, in part, on how the root system adapts to changes in aerial temperature and CO2 concentration. This study showed that roots explored more of the soil profile as aerial temperature increased, and that root distribution down the soil profile was more uniform in elevated [CO2].

Technical Abstract: Understanding crop response to climate change requires knowledge of how roots respond to changes in the aerial environment. Root growth and distribution in cotton (Gossypium hirsutum L.) were examined at day/night temperatures of 15/7, 20/12, 25/17, 30/22, and 35/27 deg C and at CO2 concentrations of 350 and 700 uL L-1. Plants were grown in controlled-environment chambers with a perspex top under nearly natural daylight. Root observations were made on one 2 m2 glass side of the soil bin. Most of the roots were found in the top 0.2 m of soil. Root weight was significantly greater in the 700 uL L-1 CO2 treatment at all depths and at all temperatures. Root numbers increased with increased temperature up to 25/17 deg C. The CO2 treatment did not affect root numbers. Roots in the lower CO2 treatment were longer (root length per root axis) and penetrated the soil profile faster at the lower temperatures. In the 700 uL L-1 CO2 treatment, roots were more evenly distributed down the soil profile than in the lower [CO2] treatment. The optimum temperature for root growth was also the optimum temperature for shoot growth (30/22 deg C). The effect of elevated [CO2] was to make roots heavier, but there was no evidence that this translated into a root system with increased length and more absorbing power. Roots were shorter in elevated [CO2], penetrating the soil profile less rapidly, but perhaps more thoroughly.

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HOMOLGUE CONCENTRATIONS OF CHLOROBORNANES IN SELECTED SAMPLES FROM THE BERING/CHUKCHI SEA

RICE CLIFFORD P

Interpretive Summary: An improved method for quantitatively determining toxaphene in environmental samples was tested on samples collected from the Bering and Chukchi seas. The method involved use of negative chemical ionization mass spectrometry. The selectivity and sensitivity of this procedure permitted very low detectibility, i.e. 0.3 ng/g in sediment. The technique also permitted separate quantification of the different chlorination groups which form the complex mixture of chlorobornanes that were present in these samples.

Technical Abstract: An electron capture negative ion mass spectrometric method for quantitative determination of chlorobornanes was tested on selected samples from an arctic marine food chain. The method was sensitive down to 0.3 ppb. Detailed area counts at prescribed mass scans were collected and processed for a fish and a neuston sample. Total chlorobornane concentrations were, 1.6 ng/g for the neuston and 12.8 ng/g for the pollack. Chlorine homologue class (Cl 6 to Cl 10) concentrations for each sample were determined. Relative homologue amounts linked the neuston to an atmospheric input since it had highest concentrations of Cl 6, which is more prevalent in air, while the fish had a higher relative levels of Cl 8 and Cl 9&10 homologues indicative of the tendency for these more lipophilic homologues to concentrate in fish lipids.

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LANDSAT MSS STUDIES OF CHLOROPHYLL IN SEDIMENT DOMINATED LAKES

RITCHIE, J C; SCHIEBE, F R; COOPER, C M; HARRINGTON, J A

Interpretive Summary: The analyses of the relationship between chlorophyll-a, suspended sediments, and radiance and reflectance data calculated from the Landsat MSS sensor data suggest that MSS data will not be useful for monitoring chlorophyll-a in lakes and reservoirs whose optical properties are influenced by suspended sediments. The combination of increased reflectance as suspended sediments (particles) increase combined with the decreased concentration of chlorophyll-a with increasing suspended sediments causes the broad band (0.1 um) MSS data signal to be so dominated by reflectance from the suspended sediments that the absorption areas due to chlorophylls are masked. Routine monitoring of chlorophylls with MSS or TM data will not be useful in sediment laden lakes. Satellite monitoring of chlorophylls in these systems must wait for satellites with higher spectral resolution such as HIRIS.

Technical Abstract: Landsat MSS can provide valuable data on surface suspended sediments in inland lakes and reservoirs. In this study, chlorophyll in three sediment dominated lakes in agricultural watersheds in the Lower Mississippi Valley was measured and compared with MSS data for 107 dates between December 1976 and August 1988. Chlorophyll-a concentrations decreased exponentially as suspended sediment concentrations increased. Radiance and reflectance calculated from MSS band 2 and 3 data increased as a function of increasing suspended sediment concentrations. Radiance in all MSS bands decreased as chlorophyll-a concentrations increased, however no significant pattern of decrease related to chlorophyll-a concentration and MSS data could be determined. Thus measurement of chlorophyll-a with broad band (0.1 um) MSS data in sediment laden waters will not be effective since the detection of the increased absorption of radiation due to increasing chlorophyll is masked by the spectral reflectance due to suspended sediments. Broad band MSS and probably TM data will provide only limited information on chlorophyll in lakes dominated by sediment. Satellite remote sensing of chlorophyll in sediment dominated systems will require high spectral resolution data especially in the chlorophyll absorption areas.

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MEASURING CHLOROPHYLL IN SEDIMENT LADEN WATERS USING LANDSAT MSS DATA

RITCHIE, J C; SCHIEBE, F R; COOPER, C M; HARRINGTON, J A

Interpretive Summary: Analyses of the relationship between chlorophyll, suspended sediments, and radiance or reflectance data from the Landsat MSS sensor suggest that MSS data will not be useful for monitoring chlorophyll in inland waters where optical properties are significantly influenced by suspended sediments. The combination of broad band reflectance by suspended sediment particles and narrow band absorption by chlorophyll means that the broad band MSS data signal to be so dominated by reflectance from the suspended sediments that the absorption areas due to chlorophyll are masked. The problem is further complicated by an increase in reflectance as suspended sediment increases and a decrease in chlorophyll as concentration of suspended sediment increases. Thus as suspended sediment increases there is less absorption due to chlorophyll. Therefore routine monitoring of chlorophyll with broad band MSS or TM data will not be useful in suspended sediment dominated waters. Monitoring chlorophyll in these systems with remote sensing techniques will require the deployment of instruments with higher spectral resolution at the chlorophyll absorption maximum.

Technical Abstract: While Landsat Multispectral Scanner (MSS) can provide valuable data about surface suspended sediments in inland waters; monitoring chlorophyll using MSS data in waters dominated by suspended sediments has been questioned. A general pattern of a decrease in the concentration of chlorophyll as concentrations of suspended sediment increased was found. Radiance and reflectance calculated from MSS increased as a function of increasing suspended sediment. Radiance and reflectance calculated from MSS decreased as chlorophyll increased, however no significant pattern of decrease related to the concentration of chlorophyll and MSS data could be determined. Thus measurement of chlorophyll with broad band MSS data in waters dominated by suspended sediments will not be effective since the detection of the increased absorption of radiation due to increasing chlorophyll is masked by the increased spectral reflectance due to suspended sediments. Broad band MSS and TM data will provide only limited information on chlorophyll in inland waters dominated by suspended sediment. Remote sensing of chlorophyll in suspended sediment dominated systems will require high spectral resolution data at the chlorophyll absorption areas.

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SELECTION OF SOYBEAN LEAVES WHICH YIELD MESOPHYLL CELL ISOLATES WITH MAXIMAL RATES OF CO2 AND NO2- PHOTOASSIMILATIONS

ROBINSON, J M

Interpretive Summary: An ongoing study of the positive and negative effects that nitrogen fertilizer over-use as well as elevated CO2 levels exert upon various sites associated with leaf photosynthetic carbon and nitrogen metabolism in soybean plants. Because of ease of testing, it often has been an advantage to examine isolates of intact soybean leaf cells for the sensitivity of their carbon and nitrogen metabolic pathways to elevated inorganic nitrogen and carbon dioxide. However, a problem often encountered when assaying photosynthetic metabolism in soybean mesophyll leaf cell isolates was that of poor reproducibility in rates of net 14CO2 fixation and NO2- photoreduction. This problem has been solved by taking advantage of the fact that soybean source leaflets repeatedly display their most active in vivo net CO2 fixation rates at the point in time that leaflets reach their maximal area. An additional advantage is that soybean leaflets reach their maximal blade length at the same point that they attain there maximal leaflet area. By monitoring the attainment of maximal leaflet length, this expedited selection newly matured leaflets which were found to yield mesophyll cell isolates displaying the maximal rates of both light dependent CO2 fixation and nitrite reduction (to the amino nitrogen level). The procedures elucided offer a rapid method for fast selection of mature leaf tissue that yields isolates of photosynthetic cells which routinely display maximal metabolic activities.

Technical Abstract: A problem often encountered when assaying mesophyll cell isolates prepared from mature soybean leaves, was poor reproducibility in rates of net 14CO2 fixation and NO2- photoreduction. Soybean source leaves repeatedly displayed their most active net CO2 fixation in the period from attainment of maximal leaf area to approximately two to five days subsequent to that point. An advantage was that when soybean leaflets of each leaf reach their maximal area they also have reached their maximal leaf length from base to tip. Soybean plants (Glycine max cv. Williams) were propagated in the growth chamber with a 12 h lite-12 h dk cycle, 25C, 65% RH, and 550 umol photons/m2.sec. At 24 d post-emergence (PE), the third leaf of each plant had just attained maximum leaflet areas (approx. 110 cm2) and lengths (approx. 13 cm). leaf mesophyll cells were enzymatically isolated using pectinase from leaflet sets of leaves selected from each of the second, third, and fourth leaf positions. Maximal rates of net 14CO2 fixation (with 5 mM HCO3-) for the second, third and fourth leaf (leaflet) isolates were, respectively, 27.0, 57.0, and 41.7 umole 14CO2 fixed/mg chl.h; simultaneously maximal rates of NO2- photoreduction (1mM NO2-) were, respectively, 4.4, 8.1, and 0.0 umole NO2- reduced/mg chl.h. These studies made it clear that in order repeatedly to attain reproducible maximal rates of leaf cell isolate net 14CO2 photoassimilation and NO2- photoreduction, it always was necessary to select the newest, fully expanded leaves (e.g. leaf number 3) for cell isolation. Leaves from several plants only were pooled if they were excised from identically the same node per plant.

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ACCLIMATION OF SOYBEAN LEAF CO2 PHOTOASSIMILATION AND LINEAR PHOTOSYNTHETIC ELECTRON TRANSPORT TO NITROGEN LIMITATION

ROBINSON, J M

Interpretive Summary: A problem in crop plant production is the lack of understanding of mechanisms by which plants are able to adjust to nitrogen deficiencies and simultaneously are able to maintain productivity. Nitrogen sufficient soybean plants were those continuously supplied from emergence with 12 mM N (6 mM NO3- plus 6 mM NH4+) while N limited plants were those continuously supplied from emergence with 6 mM N (3mM NO3- plus 3 mM NH4+). Growth analyses consistently demonstrated that there was a 25 to 30% decline in shoot growth in N limited relative to N sufficient plants. However, the roots of N limited compared with N sufficient plants displayed the same or slightly greater dry weight. The chlorophyll (Chl) per unit area of mature leaves was 40 to 63% less in N limited compared with N sufficient plants, but CO2 fixation rates were identical, or nearly so, in both treatments when rates were expressed on a leaf area basis. Linear electron transport rates compared in plastids isolated from leaves of both N limited and N sufficient plants indicated that Chl-protein complexes per plastid and plastids per unit leaf area were adequate to support normal rates of foliar CO2 fixation in N limited plants. Many species of crop plants, when subjected to N stress, are more susceptible to water stress. Maintenance of normal root size in N limited soybean plants reflected the strategy to search for both water and soil nitrogen. This study provides information to crop breeders who are searching for heritable mechanisms (traits) by which plants cope with nutrient stress.

Technical Abstract: A study was undertaken to examine potential mechanisms by which soybean plants were able to acclimate their foliar photosynthetic rates and photosynthate partitioning patterns to cope with a mild, but continuously imposed nitrogen limitation. Nitrogen sufficient soybean plants (Glycine max (L.) Merr. cv Williams) were those continuously supplied from emergence with 12 mM N (6 mM NO3- plus 6 mM NH4+) while N limited plants were those continuously supplied from emergence with 6 mM N (3mM NO3- plus 3 mM NH4+). Growth analyses consistently demonstrated that there was a 25 to 30% decline in shoot growth in N limited relative to N sufficient plants. However, the roots of N limited compared with N sufficient plants displayed the same or slightly greater dry weight. Major source leaves (3 leaflets) of N limited compared with N sufficient plants were of nearly identical areas, and these leaves were employed for measurements of photosynthetic rates and photosynthates. The chlorophyll (Chl) per unit area of mature leaves was 40 to 63% less in N limited compared with N sufficient plants, but CO2 fixation rates were identical or nearly so in both treatments when expressed on a leaf area basis. Linear electron transport rates compared in chloroplast lamellae (thylakoids) isolated from leaves of both N limited and N sufficient plants, indicated that Chl-protein complexes per plastid and plastids per unit leaf area were adequate to support normal rates of foliar CO2 fixation in N limited plants. Many species of N limited plants are more susceptible to water stress. Accretion of normal root size in N limited soybean plants reflected the strategy for the roots to maintain their ability both to search for both water and soil nitrogen.

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ACCLIMATION OF YOUNG SOYBEAN PLANTS TO HIGH CO2 LEVEL INCREASES THE FOLIAR CO2 COMPENSATION POINT AND DARK RESPIRATION RATE

ROBINSON, J M

Interpretive Summary: As part of the continuing effort to understand the influence that elevated atmospheric CO2 levels will exert upon future crop plant productivity, A study was made of how elevated CO2 levels will influence the photosynthetic and respiratory metabolism in soybean plant leaves. When soybean plants were acclimated to concentrations of CO2 above 350 ppm, for example 1000 ppm, there was an increase in their foliar photosynthetic CO2 assimilation rate as much as 1.5 times, which ultimately resulted in a doubled biomass accumulation. In high CO2 plants, there was a dramatic increase in the CO2 concentration point where leaf CO2 assimilation and respiration rates are just balanced, and this was a reflection of elevated foliar mitochondrial respiration in the light. In high CO2 exposed plants, the higher foliar respiration rate apparently was brought on by increased levels and availability of respiratory substrates, e.g. sucrose and starch. Increased plant growth was positively correlated with the increased foliar respiration rate. No inhibition of maximal foliar CO2 assimilation capacity in leaves of high CO2 soybean plants was found. Comparative measurements of foliar net CO2 photoassimilation rate as a function of CO2 concentration revealed a repression of the ability of the source leaves of high CO2 soybean plants to absorb, transport and/or concentrate CO2 when CO2 was at present at levels below 600 ppm. However, this did not inhibit plant growth in high CO2 plants, since their foliar CO2 absorption mechanism(s) had adapted to the presence of 1000 ppm CO2. This research provides data to plant ecologists and crop modelers to enable them to predict plant behavior at elevated CO2 levels.

Technical Abstract: A study was undertaken to further examine the influence that high CO2 acclimation exerts on soybean foliar photosynthetic carboxylation capacity, CO2 compensation concentration (in the light), and dark respiration. Glycine max (L.) Merr. cv Amsoy plants were propagated in growth chambers maintained with 650 uE/m2.s white light, 14 h light-10 h dark cycle, 27C continuous, and 65% RH, for 10 days post-emergence (PE) in an ambient atmosphere containing 350 ppm CO2 (normal CO2 plants). At 10 days PE one-half of the plants were transferred to a growth chamber with identical conditions except that the atmosphere in the chamber contained CO2 at 1000 ppm; these plants were acclimated for 12 additional days (high CO2 plants). CO2 enrichment of soybean plants increased CO2 photoassimilation rate and doubled biomass accumulation. There was a dramatic increase in the foliar CO2 compensation concentration (measured in the light), and this was a reflection of elevated foliar mitochondrial respiration in the light. In high CO2 exposed plants, the higher foliar respiration rate apparently was brought on by increased levels and availability of respiratory substrates. Comparative measurements of foliar net CO2 photoassimilation rate as a function of CO2 concentration revealed a repression of the ability of the source leaves of high CO2 soybean plants to absorb, transport and/or concentrate CO2 when CO2 was at present at levels below 600 ppm. However, this did not inhibit plant growth in high CO2 plants, since their foliar CO2 absorption mechanism(s) had adapted to the presence of 1000 ppm CO2

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ACCLIMATION OF SPINACH PLANT FOLIAR PHOTOSYNTHETIC CARBON METABOLISM AND DARK RESPIRATION TO ELEVATED ATMOSPHERIC CO2 LEVEL

ROBINSON, J M

Interpretive Summary: As part of the continuing effort to understand the influence that elevated atmospheric CO2 levels will exert upon future crop plant productivity, a study was made of how elevated CO2 levels will influence the photosynthetic and respiratory metabolism in spinach plant leaves. When spinach plants were acclimated to high CO2 concentrations, e.g. 1000 ppm, and compared with control plants simultaneously grown at normal CO2 levels, e.g. 350 (ppm), there was as much as a 1.4-fold increase in their rates of photosynthetic CO2 assimilation in leaves. Higher photosynthesis rates in the leaves of high relative to normal CO2 plants ultimately resulted in a doubled dry mass per plant. As in the case of high CO2 acclimated soybean, there was a dramatic increase in the CO2 concentration point and this was a reflection of elevated foliar mitochondrial respiration in the light. The higher foliar respiration rate apparently was brought on by increased levels and availability of respiratory substrates, e.g. sucrose and starch. Activities of leaf photosynthetic enzymes, e.g ribulose-1,5-bisP carboxylase (Rubisco), were 1.2-1.5 times higher in chloroplasts prepared from high compared with normal CO2 plant leaves. Thus, in high CO2 adapted plants, increased CO2 fixation was due mainly to the higher CO2 level available to Rubisco, but increased activities of plastid enzymes may have been a contributing factor. This research provides information to plant ecologists and crop modelers to enable them to predict plant behavior at elevated CO2 levels.

Technical Abstract: Foliar photosynthetic metabolism and respiration rates were examined in Spinacia oleracea cv Wisconsin Dark Green plants which were exposed to high CO2 levels for 15 days beginning at 21 days after emergence of the plants. At 21 days post-emergence, plants were acclimated for 15 additional days in high CO2 (1000 ul CO2/l air) with control plants at normal CO2 (350 ul CO2/l air). Typical source leaf net photosynthesis rates (expressed as umol CO2 fixed per dm2.h) in high and normal CO2 plants were, respectively, 1034+/-40 (measured in 1000 ul CO2/l air) and 751+/-54 (in 350 ul CO2/l air). In high relative to normal CO2 plants, growth rate was doubled, and leaf photosynthate levels, e.g. sucrose, were 1/3 higher. High carbohydrate status caused mitochondrial (dark) respiration rates, apparently ongoing in light, to double in magnitude. Activities of ribulose-1,5-bisP carboxylase (Rubisco), fructose-1,6- bisphosphate (C-1) phosphatase, and glyceraldehyde-3-phosphate dehydro- genase were 1.2-1.5 times higher in chloroplasts prepared from high compared with normal CO2 plant leaves. There was no additional activity of Rubisco conferred by suppling excess units of carbonic anhydrase. Thus, in high CO2 adapted plants, increased CO2 fixation was due mainly to the higher CO2 level available to Rubisco, but increased activities of plastid enzymes may have been a contributing factor. Higher foliar "dark", or mitochondrial respiration rate, ongoing in the light, suggested an increased photosynthate (anaplerotic) flow into the tricarboxylic acid cycle.

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ATRAZINE MOVEMENT IN SOIL: COMPARISON OF FIELD OBSERVATIONS AND PRZM SIMULATIONS

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Interpretive Summary: Variable levels of atrazine (the most widely used herbicides in corn production) have been reported within the root zone of corn and shallow groundwater under various tillage practices. Although, atrazine has usually have been found only at trace levels, the long-term effect of continuous atrazine application on the quality of surface and shallow groundwater is not fully understood. During the last decade, a number of management models have been developed for the purpose of comparing pesticides formulations, sites, etc. However, such model(s), after being tested and calibrated, can also be used to examine the long-term effects of various processes that control pesticides fate and mobility under different management scenarios. In this study, we have investigated the predictive capability of the Pesticide Root Zone Model (PRZM) by comparing our field observation of atrazine with PRZM prediction values for three growing seasons (1986-1988). Overall, PRZM simulations compared well for the atrazine residues in the top 10 cm soil depths in conventional-till plots, but over-estimated for no-till plots. Although, PRZM model prediction was accurate for the surface (0-10 cm) soil in the tilth plots, the model did not predict transport of atrazine to the lower depths as indicated by actual data from all three years. These results show that the PRZM model does not account for the preferential transport of atrazine into the lower soil profile in the no-till system.

Technical Abstract: The pesticide root zone model (PRZM) was used to predict movement of the herbicide atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino) -s-triazine] under no-till (NT) and conventional-till (CT) corn production systems. Simulation values of atrazine obtained using site-specific soil and environmental data were compared with actual values measured in samples taken from the root zone of NT and CT plots, during 1986, 1987, and 1988. The mean concentration of atrazine in soil at each sampling time, depth and tillage treatment (NT or CT), was estimated based on type of distribution (normal or lognormal). Overall, PRZM simulations successfully predicted atrazine residues in the top 10 cm in CT plots, but over-estimated atrazine levels in NT plots. In 1986, the mean measured atrazine level taken 6 days after application from the top 10 cm depth in NT plots, was about 385 with a standard error (SE) of 154. The PRZM prediction for the same depth increment was 674 ug kg-1. Although, PRZM prediction was accurate for the top 10 cm of CT (actual mean 428 and SE of 178, PRZM prediction of 500 ug kg-1), predicted values for atrazine transport did not match measured values in the lower depths. PRZM simulations underestimated atrazine transport to the lower depths (20 to 30 cm), especially in the NT system. This indicates that the PRZM model does not account for preferential transport of atrazine into the lower soil depths in the NT system.

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SHALLOW GROUNDWATER: EFFECT OF TILLAGE AND RAINFALL TIMING.

SADEGHI, A M; ISENSEE, A R

Interpretive Summary: The combined effect of tillage and rainfall timing on the movement and distribution of pesticides has not been clearly understood. Residue values in the 0 - 30 cm soil depth and in shallow groundwater in 1987, 1988, and 1989 were used to demonstrate this interactional effect on the spatial distribution of atrazine in corn production. These three years were selected since nearly the same amount of rain fell, but at different times and intensities, within the period between atrazine application and the first sampling. Overall, the average atrazine residues in the top 10 cm soil of conventional-till plots were much higher than in no-till plots in all years, regardless of the rainfall timing. Highest atrazine residue levels in shallow groundwater were found in the samples collected from the no-till plots three days after the first rain event in 1988. However, the concentrations decreased markedly by 14 and 40 days post-application. The relatively high residue levels in 1988 presumably resulted from the first rain event in which contributed 48 mm of precipitation fell in a two-day rain that began twelve hours after application and lasted about 2 days. The average residue levels of atrazine in the wells below the clay layer in the no-till plots were higher than in the conventional-till plots in all three years.

Technical Abstract: A study was initiated in 1986 to compare the effects of no-till (NT) and conventional-till (CT) corn production on the movement of pesticides to groundwater. Specifically, the effect of rainfall timing on the spatial distribution of atrazine in the 0 - 30 cm soil depth and in groundwater less than 1 m deep was evaluated in 1987, 1988, and 1989. Nearly the same amount of rain fell, but at different times and intensities, between application and first sampling during these years. The average atrazine residues in the top 10 cm soil of the CT plots were much higher than the NT plots in all years. The difference was 23% in 1987 (first rain was 3 d after application), 56% in 1988 (12 h after application), and 63% in 1989 (6 d after application). Atrazine levels were 663 and 424 ug/L in samples collected from wells above the clay layer in the NT plots three days after the first rain in 1988. Concentrations decreased to 133 and 105 ug/L and 6 and 5 ug/L after 14 and 40 days. The high residues in 1988 resulted from 48 mm precipitation that fell over 2 days beginning 12 h post-application. The average levels of atrazine in the wells below the clay layer in the NT plots were higher than the CT plots in all years. The semivariograms for residues in the 0 to 30 cm soil depth showed that the residue values were spatially related for the separation distance of less than 16 m. For the well water samples, this distance was estimated to be about 30 m.

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SPATIAL DISTRIBUTION OF ATRAZINE RESIDUES IN SOIL AND SHALLOW GROUNDWATER: EFFECT OF TILLAGE AND RAINFALL TIMING.

SADEGHI, A M; ISENSEE, A R

Interpretive Summary: The combined effect of tillage and rainfall timing on the movement and distribution of pesticides has not been clearly understood. Residue values in the 0 - 30 cm soil depth and in shallow groundwater in 1987, 1988, and 1989 were used to demonstrate this interactional effect on the spatial distribution of atrazine in corn production. These three years were selected since nearly the same amount of rain fell, but at different times and intensities, within the period between atrazine application and the first sampling. Overall, the average atrazine residues in the top 10 cm soil of conventional-till plots were much higher than in no-till plots in all years, regardless of the rainfall timing. Highest atrazine residue levels in shallow groundwater were found in the samples collected from the no-till plots three days after the first rain event in 1988. However, the concentrations decreased markedly by 14 and 40 days post-application. The relatively high residue levels in 1988 presumably resulted from the first rain event in which contributed 48 mm of precipitation fell in a two-day rain that began twelve hours after application and lasted about 2 days. The average residue levels of atrazine in the wells below the clay layer in the no-till plots were higher than in the conventional-till plots in all three years.

Technical Abstract: A study was initiated in 1986 to compare the effects of no-till (NT) and conventional-till (CT) corn production on the movement of pesticides to groundwater. Specifically, the effect of rainfall timing on the spatial distribution of atrazine in the 0 - 30 cm soil depth and in groundwater less than 1 m deep was evaluated in 1987, 1988, and 1989. Nearly the same amount of rain fell, but at different times and intensities, between application and first sampling during these years. The average atrazine residues in the top 10 cm soil of the CT plots were much higher than the NT plots in all years. The difference was 23% in 1987 (first rain was 3 d after application), 56% in 1988 (12 h after application), and 63% in 1989 (6 d after application). Atrazine levels were 663 and 424 ug/L in samples collected from wells above the clay layer in the NT plots three days after the first rain in 1988. Concentrations decreased to 133 and 105 ug/L and 6 and 5 ug/L after 14 and 40 days. The high residues in 1988 resulted from 48 mm precipitation that fell over 2 days beginning 12 h post-application. The average levels of atrazine in the wells below the clay layer in the NT plots were higher than the CT plots in all years. The semivariograms for residues in the 0 to 30 cm soil depth showed that the residue values were spatially related for the separation distance of less than 16 m. For the well water samples, this distance was estimated to be about 30 m.

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ROOT EXTRACTION OF NUTRIENTS ASSOCIATED WITH LONG-TERM SOIL MANAGEMENT

SHARPLEY, A N; MEISINGER, J J; POWER, J F; SUAREZ, D L

Interpretive Summary: One of the main challenges facing agricultural research at the present time, is to identify farming practices that will maintain long-term soil fertility and crop yields, while at the same time allowing a reduction in the amount of fertilizer chemicals added and number of tillage operations. From our current knowledge of processes determining the uptake of nutrients by crops, several areas of research are needed to meet this challenge. These areas of research involve determining the effect of tillage practice, fertilizer type and placement, residue management, and crop selection on the amount of water and plant available nutrients in the volume of soil where roots are actively growing. Results from this research should enhance the sustainability of agricultural production systems.

Technical Abstract: One of the main challenges of agricultural research is to identify management practices that maintain long-term soil fertility and crop production with reduced chemical inputs and tillage operations. This paper reviews the current state of knowledge and research needs concerning the impact of soil management on the root extraction of nutrients. Manageable variables controlling soil-water content, nutrient availability, root growth and development, and thereby, root extraction of nutrients are interactive, complex, and dynamic. There is, thus, a need for team research involving physical, chemical and biological disciplines. This should focus on tillage practice, fertilizer type and placement, residue management, and crop selection to coincide the positional availability of soil water and nutrients during periods of active root growth and nutrient uptake. It is also important to determine the relative importance of soil properties on organic matter cycling as influenced by soil fauna and flora, tillage, and crop rotation. Information from identified research needs and integration of existing knowledge into management systems should facilitate progress towards enhancing sustainable soil fertility.

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INFLUENCE OF RAINFALL INTENSITY AND CROP RESIDUE ON LEACHING OF ATRAZINE IN INTACT NO-TILL SOIL CORES

SIGUA, G C; ISENSEE, A R; SADEGHI, A M

Interpretive Summary: Pesticides applied to no-till (NT) fields are often intercepted by a combination of crop residue and living vegetation. The effect this residue has on pesticide leaching as a function of rainfall amount and intensity is not well known and is the objective of this research. Intact soil cores (with crop residue) from NT fields were treated with 14C atrazine and subjected to two pore volumes of simulated rain applied at 3 to 12 mm/h. The crop residue on a second set of intact soil cores was adjusted from 0 to 8000 kg/ha, treated with 14C atrazine and subjected to two pore volumes of rain at 9 mm/h. Atrazine leaching through a third set of soil cores covered with dead compared to freshly harvested crop residue was evaluated as above. Both the amount and rate of atrazine leaching were greater at high (9 and 12 mm/h) compared to low (3 and 6 mm/h) rainfall intensities. Increasing amounts of crop residue from 2000 to 8000 kg/ha (25 to 100% of normal crop residue levels) decreased leaching of atrazine through soil cores. Freshly harvested crop residue reduced leaching more than dead crop residue. These results help explain observed variability in field experiments and indicate that potential pesticide leaching under field conditions is highly dependent on interactions between field conditions and rainfall amount and intensity.

Technical Abstract: We investigated the effect of rainfall intensity and crop residue on 14C-labeled atrazine (2-chloro-4-ethylamino-6-isopropylamino -s-triazine) and bromide movement through no-till (NT) soil cores. Undisturbed soil cores (10 cm diameter by 8 cm deep) were taken from the surface of a NT corn field, surface treated with 1.3 kg/ha atrazine and 150 kg/ha KBr and subjected to uniform amounts of simulated rainfall at 3, 6, 9, or 12 mm/h. The crop residue on another set of cores was adjusted from 0 to 8000 kg/ha, treated with atrazine as above and subjected to 9 mm/h simulated rain. A third experiment compared recently harvested vegetation to dead crop residue on their effect on atrazine leaching. Overall, the transport of surface applied atrazine and Br were significantly ($p<0.01$) affected by rainfall intensity and crop residue. An average of 56% and 3.8% and 36% and 2.3% of the applied atrazine and Br were leached at the 12 mm/h and 3 mm/h rates, respectively. Covering soil cores with 2000 to 8000 kg/ha of crop residue reduced atrazine leaching by 19 to 28%, respectively, compared with cores without crop residue. Soil cores covered with 8000 kg/ha recently harvested vegetation reduced atrazine leaching 57% compared to cores covered with comparable amounts of dead crop residue.

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ROLES OF BIODEGRADATION AND SORPTION IN APPARENT LOSSES OF ATRAZINE FROM CONVENTIONAL VS. NO-TILL SOILS

SHELTON, D R; SADEGHI, A M; KARNS, J S; HAPEMAN, C J; ISENSEE, A R

Interpretive Summary: Atrazine is the most widely used herbicide in the U.S., with 69% of all corn acreage treated. Atrazine is also the most frequently detected pesticide contaminant in groundwater. Field studies were initiated in 1987 at the Beltsville Agricultural Research Center (BARC) to validate models (e.g., PRZM) for predicting leaching of atrazine to groundwater. These models require inputs for other major fates of atrazine, such as run-off, volatilization, and biodegradation in order to determine the amount of atrazine available for leaching. The present study was conducted in order to determine the amount of atrazine lost to biodegradation in field plots. Previous research suggests that rates of biodegradation in soil are relatively slow. Our data, however, indicates that rates of atrazine biodegradation are relatively rapid, such that a significant percentage of applied atrazine is lost through biodegradation and is not available for leaching. Based on these inputs, more accurate predictions regarding rates of leaching of atrazine to groundwater can be obtained.

Technical Abstract: Studies were conducted to estimate losses of atrazine attributable to biodegradation and sorption in field plots at the Beltsville Agricultural Research Center (BARC). Mineralization experiments using labelled atrazine indicated the potential for rapid rates of biodegradation. Further studies, in which soluble and sorbed atrazine pools were monitored independently, were also conducted to assess the effect of a drying and rewetting cycle on atrazine sorption and biodegradation as a function of various levels of added crop residues (0, 5 and 10% dried-ground corn stalks). Drying and rewetting resulted in decreased extraction efficiencies of sorbed atrazine; the effect was most pronounced with added corn stalks. In addition, rapid rates of biodegradation were observed in corn stalk amended soils shortly after rewetting. Collectively, these data suggest that apparent losses of atrazine in field studies may be due to rapid rates of biodegradation and/or decreased extraction efficiencies. However, the relative importance of these fates probably vary between no-till vs conventional-tillage plots.

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ESTIMATION OF RATES OF GRANULAR CARBOFURAN DISSOLUTION IN SOIL

SHELTON, D R; SADEGHI, A M; ISENSEE, A R

Interpretive Summary: Soil-borne insect pests are a major threat to crop (corn) production. Unlike foliar insect pests, which are amenable to integrated pest management techniques, soil applied granular pesticides are required for control of soil-borne insects. The use of biodegradable pesticides is desirable in order to minimize the potential for groundwater contamination. However, soil-applied pesticides which are degraded rapidly can result in a loss of efficacy and hence, significant yield losses. The development of pesticides of moderate persistence, or the implementation of management strategies using non-persistent pesticides, is dependant on accurate information regarding rates of biodegradation, minimum lethal pesticide concentrations, and rates of release of pesticides from granules. Previous studies have documented rates of microbial degradation and lethal pesticide concentrations. However, no studies have documented rates of pesticide leaching/dissolution from granules. This study provides quantitative data on the rate of release of pesticides from granules. This information may be used to develop methods for minimizing pesticide contamination while also maximizing pesticide efficacy.

Technical Abstract: Losses of efficacy of carbofuran are due to rates of microbial degradation which exceed rates of granular leaching/dissolution, resulting in carbofuran concentrations below the lethal threshold needed for control. Rates of carbofuran leaching from granules as a function of rainfall intensity/infiltration rate, and granular dissolution as a function of time, were estimated using a rain simulation device. Rates of leaching (1.5 ug/mg granules normalized to 1 cm/hr) were positively correlated with rainfall/infiltration. Rates of granular dissolution were linear up to 72 hrs (0.28 ug/mg granule. Adjusted for field conditions, ca. 50 hrs of rainfall would be required to leach carbofuran from granules or ca. 11 days (at field capacity) for dissolution of granules. Soil solution concentrations would be ca. 16 ppm, or 4 ppm bulk soil. Rates of spherical carbofuran diffusion from a theoretical granule were calculated. Carbofuran concentrations decreased rapidly as a function of distance. However, these high localized carbofuran concentrations may result in high population densities of carbofuran-degrading microorganisms in the vicinity of granules. These data suggest that losses of efficacy may result either from the complete leaching/dissolution of granules and biodegradation before larvae hatch, or rates of biodegradation which exceed rates of granular leaching/dissolution after larvae hatch.

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MELOIDOGYNE INCOGNITA AND ROTYLENCHULUS RENIFORMIS AND ASSOCIATED SOIL TEXTURES FROM SOME COTTON PRODUCTION AREAS OF TEXAS

STARR, J L; HEALD, C M; ROBINSON, A F; SMITH, R G; KRAUSZ, J P

Interpretive Summary: A survey was conducted in Texas to acquire additional information regarding the geographical distributions of the two major nematode parasites of cotton, viz., the cotton root-knot nematode and the reniform nematode. In new areas where these nematodes were found, their incidence was compared with data on soil texture. A previously observed tendency for the reniform nematode to occur in finely textured soils and for the cotton root-knot nematode to occur in sandy soils was confirmed. This information is valuable to farmers, consultants, and extension specialists who need to know where nematode problems in cotton production areas are most likely to occur.

Technical Abstract: The incidence of Meloidogyne incognita and Rotylenchulus reniformis on cotton in 33 counties that account for nearly 60% of the 2.2 million hectares planted to cotton in Texas was determined in 1989-1992. Meloidogyne incognita was commonly found in the Southern High Plains and Brazos River Valley regions of Texas, but rarely found in the Central Blacklands, Coastal Bend, Low Plains, or the Upper Gulf Coast regions. Rotylenchulus reniformis was widely distributed in the Brazos River Valley and found occasionally in the Upper Gulf Coast but was less widely distributed than M. incognita. Meloidogyne incognita was found only rarely in soils with greater than 40% clay content whereas Rotylenchulus reniformis was frequently found in finely textured soils but was less common in soils with greater than 40% sand content. Soil pH ranged from 7.5 to 8.5 and was not correlated with the incidence of either species.

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INFLUENCE OF SAMPLE SIZE ON CHEMICAL AND PHYSICAL SOIL MEASUREMENTS

STARR, J L; MEISINGER, J J; PARKIN, T B

Interpretive Summary: The volume of soil sampled for measurement of various soil properties may be important for soil properties that undergo rapid transformations or can change abruptly within a small spatial area. The purpose of this study was to investigate the influence of the size of soil samples collected on the magnitude and variability of typically measured physical, chemical, and biological properties of the soil: soil pH, water content, bulk density, nitrate and phosphorus content, and denitrification rates. Denitrification rates, nitrate, and ortho-P values were generally lognormally distributed, while bulk density, water content, and pH were usually normally distributed. All soil parameters except bulk density exhibited spatially dependent results. The effect of sample size varied somewhat with the parameter in question. The most consistent sample size effect was with the smallest diameter samples giving somewhat unreliable sample means, more highly asymmetrical frequency distributions and higher variances. This study provided insight on the influence of sample size on commonly measured soil parameters, and should be useful to scientists and to soil and agronomy extension specialists in choosing the most appropriate size of soil samples to collect for subsequent laboratory analyses.

Technical Abstract: Variation of measured soil properties may be confounded by errors due to under-sampling the site, sample handling, and analyses. This study was conducted to evaluate the influence of the size of soil samples collected on the magnitude and variability of typically measured physical, chemical, and biological properties of the soil. The experiment was conducted at Beltsville, MD, on a Beltsville silt loam soil (fine-loamy, mixed, mesic Typic Fragiudult). Surface 16-cm soil samples were collected using five different sized soil coring tubes, 1.7 to 5.4 cm in diam., and one 20- by 30-cm block. Thirty-six of each sample size were collected twice before and twice after planting corn (Zea mays L.). Denitrification rates, NO3-N, and ortho-P values were generally lognormally distributed, while bulk density (Db), water content, and pH were usually normally distributed. All soil parameters except Db exhibited spatially dependent results. The effect of sample size varied with the parameter in question. The most consistent size effect was with the smaller diameter samples giving biased means relative to the block sample means, greater skewness, or higher variances.

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THE S-TRIAZINE HYDROLASE GENE TRZA FROM RHODOCOCCUS CORALLINUS: CLONING AND NUCLEOTIDE SEQUENCE

STEFFENS, W; MULBRY, W W

Interpretive Summary: The widespread use and relative persistence of s-triazine herbicides such as atrazine has lead to increasing concern about surface and groundwater contamination by these compounds. Alkylated s-triazine compounds such as atrazine are relatively recalcitrant to biodegradation processes in soil. Few microorganisms have been isolated that degrade these compounds at rates that would be useful for detoxifying pesticide wastes. In this study, scientists characterized a bacterial gene that is responsible for an unusual enzyme that removes chlorines from certain s-triazines. An understanding of this gene will aid in the isolation of other useful s-triazine degrading organisms and will lead to the development of better waste disposal technologies.

Technical Abstract: Using degenerate oligodeoxyribonucleotides (oligos) derived from the N-terminal sequence of an s-triazine hydrolase from Rhodococcus corallinus NRRL B-15444R, an amplification reaction was used to isolate a DNA segment containing a 57-bp fragment from the trzA gene. Based on the nucleotide (nt) sequence of this fragment, a nondegenerate oligo was synthesized and used to screen a subgenomic library of R. corallinus DNA for fragments containing trzA. A 5.3-kb PstI fragment containing trzA was cloned into Escherichia coli, and the nt sequence of a 2450-bp region containing trzA was determined. No detectable trzA expression was observed in Gram-negative strains that contained trzA under the control of the lacZ promoter. A search of DNA and protein databases for homologies to trzA revealed no significant homologies to known sequences

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SPATIAL VARIABILITY OF PREFERENTIAL TRANSPORT OF A NON-ADSORBED SOLUTE I: FIELD MEASUREMENTS

TIMLIN, D; AHUJA, L R; HEATHMAN, G

Interpretive Summary: An understanding of how soil properties influence the transport of solutes is important if we are to properly manage chemical use in agriculture and minimize pollution of groundwater. The goal of this study was to measure the horizontal and vertical spatial distribution of a non-adsorbed tracer (bromide) in a field-soil. We investigated the contribution of soil porosity to tracer recovery and variability. There was little evidence of large surface connected pores to carry tracer and water past the upper layers of soil to deep in the profile. Tracer recovery in the upper 70 cm of soil, in some cases, was very low, however, indicating bypass of the soil matrix. More of the applied tracer was recovered when the soil was initially dry and, when the porosity of the soil was high. Localized areas of high permeability in the subsoil also greatly contributed to the movement of tracer deep into the profile past the sampled area. The effect was enhanced in soils with low overall porosity. Subsurface properties had a larger effect on solute transport than did surface properties.

Technical Abstract: An understanding of how soil properties influence the transport of solutes in soils is important if we are to properly manage chemical use in agriculture. The goal of this study was to measure the horizontal and vertical spatial distribution of a non-adsorbed tracer (bromide) in a field-soil. We investigated the contribution of porosity to tracer recovery and variability. The soil at the site is a Bosville fine sandy loam (fine-mixed, thermic Albaquic Paleudalfs). The surface soil texture is fine sandy loam which grades to a clay loam in the subsoil. Strontium Bromide ($SrBr_2$) tracer was applied with a dye in a 100 or 50-mm pulse of water to eight double ring infiltrometers and the soil sampled after 48 hours at 0.1 m increments to a depth of 0.7 m. Twelve soil samples were taken at each depth with a coring device 27 mm in diameter. There were only a very few dye stains of root hairs, root channels, and pores in the soil to a depth of about 50 to 80 mm. Recoveries of Br to 0.7 m ranged from 33 to 80% applied. Br recovery was positively related to initial air filled porosity and total porosity. Recovery was inversely related to time required for the solute pulse to fully infiltrate. There was greater variability in bromide where the 100-mm pulse was applied. A large fraction of solute transport was probably through a network of interconnected mesopores less than 0.1 mm in diameter and, in the clayey subsoil, through local regions of high permeability. A smaller amount appeared to move through the soil matrix.

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COMPARISON OF THREE FIELD METHODS TO CHARACTERIZE MACROPORE FLOW CAPACITY

TIMLIN, D; AHUJA, L R; ANKENY, M D

Interpretive Summary: Surface applied chemicals may bypass the soil matrix and move directly to ground water through large, continuous pores in the soil (macropores). Macropore flow capacity is a parameter necessary to simulate water and solute movement in soils with macropores. It is defined as the difference between hydraulic conductivity under ponded conditions and conductivity under a slight negative tension (3 to 8 cm). Conductivities under a slight tension were measured by infiltrating water through a thin crust and also obtained from measurements of water content during soil water redistribution. A tension infiltrometer was also used. Macropore flow capacities obtained from the crust or redistribution measurements were similar. Flow capacities from the tension infiltrometer were higher. The redistribution method is recommended since it is convenient and other hydraulic parameters can be obtained as well.

Technical Abstract: An objective of this study was to investigate several field oriented and non-destructive methods to characterize the flow properties of both the soil matrix and macropores. Soil matrix conductivities in eight 50-cm diameter rings were measured at tensions near saturation with a thin sand-cement crust and also estimated from redistribution measurements. These were compared to conductivities measured under ponded conditions using a double ring infiltrometer. Macropore flow capacity was obtained by difference. Matrix conductivities were also obtained using a 7.6- cm dia tension infiltrometer and ponded conductivities obtained from unconfined infiltration in similar-sized rings. Conductivities from the tension infiltrometer were higher than conductivities from the crust or redistribution methods probably due to a shallow restricting layer and the effect of air entrapment on confined measurements. Macropore flow capacities obtained using crust data were similar to those obtained from redistribution data. We concluded that macropore flow capacity can be characterized by using ponded infiltration rates and matrix conductivities near saturation determined from redistribution data.

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VOLATILIZATION OF FONOFOS, CHLORPYRIFOS AND ATRAZINE FROM CONVENTIONAL AND NO-TILL SURFACE SOILS IN THE FIELD

WHANG, J M; SCHOMBURG, C J; GLOTFELTY, D E; TAYLOR, A W

Interpretive Summary: No-tillage practices are being implemented by farmers in an effort to save energy and time, and reduce soil erosion losses. The most noticeable characteristic of a no-till field in comparison to a conventionally tilled field is the plant debris layer left on the soil surface. Because no-tillage fields are not plowed or disked fertilizer and pesticides are applied to the surface over the plant debris layer. A side-by-side field experiment compared pesticide loss by volatilization from a conventionally tilled plot and a no-till plot in a corn field. The plant debris layer on the no-till plot intercepted approximately 40% of the pesticide spray application. Volatilization losses of the more volatile pesticides were greater from the no-till plot than from the conventionally tilled plot. Increased pesticide loss by volatilization from no-till fields may create a need for higher application rates and perhaps lead to more environmental contamination by airborne pesticides. The results of this study suggest the need for different pesticide application techniques on no-till fields. The use of less volatile pesticides, more efficient application techniques such as injection beneath the soil surface, and more efficient pesticide formulations such as slow release pellets are possible solutions.

Technical Abstract: We measured the effect of no-till on pesticide volatilization by conducting a side-by-side comparison of volatilization rates from no-till (NT) and conventionally tilled (CT) fields. Volatilization rates were determined using the theoretical profile shape method for 10 of the 26 days following application. Soil and mulch residues were also evaluated. Volatilization losses of fonofos (O-ethyl S-phenyl ethylphosphonodithioate) and chlorpyrifos (O, O-diethyl O-(3,5,6-trichloro-2-pyridyl) phosphorothioate) from the NT field were 2 to 4 times volatilization losses from the CT field. As much as half the application volatilized during 26 days. Volatilization of atrazine (6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine -2,4-diamine) was also greater from NT, but only 1-2% of the application volatilized. Maximum volatilization rates were usually measured at mid-day, which suggests that volatilization was not limited by soil dryness. Over the 26 days of the experiment, volatilization decreased faster than pesticide residue was depleted, suggesting residues were becoming more strongly sorbed to soil and/or mulch, or were becoming less accessible to the surface.

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ANALYSIS OF THE EFFECTS OF SOIL COMPACTION ON COTTON YIELD TRENDS

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Interpretive Summary: Cotton yields in the U. S. Cotton Belt declined from 1960 to 1980 despite improvements in technology and introductions of higher yielding cultivars. As part of the effort to examine possible causes for the yield reduction, the cotton crop model GOSSYM, was used to analyze the effects of soil compaction on cotton yield trends. Weather, soil and cultivar input data from six locations over 20 years were acquired for this study. Increases in soil bulk density due to tire traffic in the row middles were calculated and used as model input for GOSSYM model. In looking at the overall effects of wheel traffic compaction, there were no consistent trends. Compaction effects were masked and complicated by the weather and varied from location to location. In some areas, such as at College Station, wheel traffic may even have enhanced yield by changing the root/shoot partitioning in response to water stress. In other areas and soils, such as the Dundee Silt loam of the Mississippi Delta, it appears that compaction generally reduced yields. The tillage equipment which tills more rows per set of wheels might help to reduce the soil compaction due to wheel traffic.

Technical Abstract: Cotton (Gossypium hirsutum L.), yields in the U.S. Cotton Belt declined from 1960 to 1980 despite improvements in technology and introductions of higher yielding cultivars. As part of the effort to examine possible causes for the yield reduction, the cotton crop simulation model, GOSSYM, was used to analyze the effects of soil compaction on cotton yield trends. Weather, soil and cultural input data from six locations over 20 years were acquired and used for this study. Increases in soil bulk density due to tire traffic in the row middles were calculated using the Gupta and Allmaras (1987) model and input into GOSSYM. There were no consistent trends over all locations. Prior to 1974, compaction had some negative effect at Florence, SC, but due to annual in-row subsoiling, had no effect after that time. At Stoneville, MS the effects of compactions were generally detrimental but they were often masked by weather. In years of abundant moisture, wheel traffic compaction had little negative effect on yields since shallow root systems could extract sufficient moisture. In extremely dry years, predicted yields were low for both compacted and uncompacted crops. The effect of wheel compaction on yield was generally favorable at College Station, TX. The lower yielding crop, however, generally put more of its photosynthate into roots during the boll filling period. This was also true at Phoenix, AZ, where the results were erratic. At Lubbock, TX, on a clay soil the effects of simulated compaction were negligible.

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EFFECT OF FORMULATION AND TILLAGE PRACTICE ON VOLATILIZATION OF ATRAZINE AND ALACHLOR

WIENHOLD, B J; GISH, T J

Interpretive Summary: Conservation tillage practices are becoming more popular with farmers. Many of these practices have the potential for altering the environmental behavior of agricultural chemicals when compared to behavior under conventional tillage. This study was conducted to compare volatilization of atrazine and alachlor applied at rates commonly recommended to farmers as either a commercial formulation or an experimental starch encapsulated formulation from no-till fields to that from conventionally tilled corn fields in Maryland. Volatilization losses of atrazine and alachlor from no-till fields were less than from conventionally tilled fields. Starch encapsulation reduced volatilization of atrazine from no-till and conventionally tilled fields and reduced volatilization of alachlor from no-till fields. These results will aid in determining how conservation tillage practices influence the environmental fate of agricultural chemicals and determine the viability of starch encapsulation as formulation modification for controlling pesticide behavior.

Technical Abstract: Conservation tillage practices are being implemented by many farmers to conserve water and soil resources. These practices may modify the soil surface in ways that differentially effect dissipation of pesticides when compared to conventionally tilled fields. We measured volatilization of atrazine and alachlor applied as either a starch-encapsulated formulation or as a commercial formulation to adjacent no-till and conventionally tilled corn fields in Maryland. After 35 d, cumulative volatilization of alachlor from conventionally tilled fields was 14% of that applied for both formulations. Cumulative volatilization of alachlor was less from no-tilled fields with 9% of the commercial formulation and 4% of the starch-encapsulated formulation being lost. After 35 d, cumulative volatilization of the commercial formulation of atrazine from the conventionally tilled field was 9% of that applied compared to 4% of that applied to the no-till field. Starch encapsulation reduced volatilization losses of atrazine to <2% of that applied for both tillage practices. Starch encapsulation appears to be a viable formulation modification for reducing volatilization losses of herbicides, especially from no-till fields.

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CHEMICAL PROPERTIES INFLUENCING RATE OF RELEASE OF STARCH ENCAPSULATED HERBICIDES: IMPLICATIONS FOR MODIFYING ENVIRONMENTAL FATE

WIENHOLD, B J; GISH, T J

Interpretive Summary: Detection of agriculturally applied herbicides in precipitation, surface water, and ground water has lead to an increase in awareness of the potential for environmental contamination by these chemicals. This increased awareness has resulted in an increase in efforts to develop formulation modifications that influence herbicide behavior. Encapsulation of herbicides in starch granules is one formulation modification being studied. Starch encapsulation does not modify herbicide behavior of all herbicides uniformly. We measured the time required for complete release of a number of herbicides and found that time for complete release was strongly correlated with the water solubility of the encapsulated herbicide. Field studies suggest that starch encapsulation most strongly modifies herbicide behavior when the rate of release is sufficiently slow. Hence, starch encapsulation appears to be a viable technology for herbicide exhibiting a water solubility below 300 mg l -1.

Technical Abstract: Starch encapsulation is a controlled release technology which may reduce a chemical environmental contamination potential. Effectiveness of starch encapsulation in modifying environmental behavior is not uniform for all herbicides. We quantified the time required for complete release for a number of herbicides exhibiting a range of chemical properties. Time required for complete release was strongly correlated with water solubility of the encapsulated chemical. As water solubility of the encapsulated chemical decreased, time required for complete release increased exponentially. Results of field scale experiments suggests that starch encapsulation influences the environmental behavior of an encapsulation herbicide when the time required for complete release is from 14 to 21 days. Results suggest that starch encapsulation will provide a satisfactory rate of release for herbicides that have water solubilities of 20 to 300 mg l -1.

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